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Maintenance Research Master Planning Workshop

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Sponsored by Group 3 – Operations, Safety, and Maintenance of Transportation Facilities
Section C – Maintenance

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Preface

The Maintenance Research Master Planning Workshop was held on January 13, 2000, in Washington, DC. The objective of the workshop was to develop a 3-, 5-, and 10-year phased master plan of maintenance research needs. The participants included the Chairs and selected members of the 12 highway maintenance committees in Group 3 – Operations, Safety, and Maintenance of Transportation Facilities, Section C – Maintenance, plus seven individuals representing the American Association of State Highway and Transportation Officials (AASHTO) Highway Subcommittee on Maintenance, two from the Federal Highway Administration (FHWA), one from the American Public Works Association (APWA), and one from the National Association of County Engineers (NACE). Many of the participants are actively involved in a number of the participating Committees and Organizations.

Contents

Introduction

The chairs of the 12 maintenance committees in TRB Group 3 Section C formed a core unit under the leadership of Mr. Leland D. Smithson as workshop chair to develop a 3-, 5-, and 10-year phased master plan of maintenance research needs. Mr. Rodney A. Pletan (Section C Chair) and Mr. Frank N. Lisle (TRB Staff Engineer for Maintenance) served as staff support. Dr. Kenneth A. Brewer acted as agent to synthesize the workshop activity into a unified plan. The titles and scopes of the TRB Highway Maintenance Committees are listed in Appendix A.

The research needs previously identified through past committee and research workshop activities were furnished to each maintenance committee in mid-1999. The committees also were furnished copies of all the maintenance TRB "millennium papers" as a resource document. Each maintenance committee chair was asked to consult with the committee membership to identify five committee members to participate in a workshop to establish research plan priorities on January 13, 2000; and to submit their committee priority research needs in problem statement form by mid-December 1999.

The 60 research problem needs statements submitted were compiled and sent to participants at the beginning of January 2000, with a request to bring a pre-workshop assignment of candidate projects into a 3-year, 5-year, and 10-year phased research plan with no more than five projects in each phase. At the workshop the participants were assigned to four breakout groups; issued a new compilation of problem statements including 13 additional problems received after the distribution of statements; and instructed to develop a suggested research plan of five projects in each of the 3-year, 5-year, and 10-year phases.

All the participants were assembled as a committee-of-the-whole after the groups had completed their plans, to report on their work and to permit joint discussion. While the breakout groups had differences of opinion regarding priorities and the groups' reports did not agree with the pre-workshop priorities, the aggregation of the breakout groups' results provided a comprehensive master plan. The breakout groups identified six synthesis statements, four of them preliminary tasks for later research efforts. The groups also identified seven problem statements that were suggested for combining and reorganizing into five merged problem statements. The details of these recommendations are included in the following sections.

CATEGORY I: IMMEDIATE ACTION

Syntheses

The following six synthesis topics have been submitted for inclusion in the YR2000 NCHRP Synthesis Program. The title and the originating TRB, Group 3, Section C, Maintenance Committee consist of the following. The full statements are listed by submitting Committee in Appendix B.

- Procedures for Condition Assessment of Prestressed Concrete Bridges (A3C06-05)
- Best Management Practices for Controlling Invasive Roadside Weeds* (A3C07-01)

* Note: Synthesis effort is initial tasks in research project in Category IV.

- Procedures to Reduce Tire Scrap Debris on Highways* (A3C07-02)
- Outsourcing Equipment Fleet Operations (A3C08-08)
- Pavement Markings for Cold-Weather Application* (A3C12-04)
- Criteria for Removing Concrete and Cleaning Reinforcing Steel in Bridge Rehabilitation* (A3C15-02)

Submission to NCHRP for Consideration by AASHTO Standing Committee on Research (SCOR)

Each Section in TRB Technical Activities Division Group 3 is permitted to identify two high-priority research needs for submission to National Cooperative Highway Research Program (NCHRP) for consideration by the AASHTO SCOR. Ordinarily, each of the 12 committees in Section C (Maintenance) is allowed to submit one research problem statement, and a screening committee of the entire section evaluates these problem statements to select the top two research priorities. This year the top two research needs coming out of the workshop were submitted from Section C (Maintenance). The full statements are listed in Appendix B.

- Asset Management-Framework for Allocating Resources Among Maintenance Assets and Services (A3C01-01)
- Influence of Sealing Transverse Contraction Joints on the Overall Performance of Concrete Pavements (A3C13-01)

CATEGORY II: 1-to-3–YEAR PHASE

Workshop participants were asked to formulate, from the research needs problem statements available to them and from their own expertise, a research phase consisting of projects that should be started within the next three years. The need to start a project in the short-term future could be based on a perception that the research need was so pressing that delay in obtaining results to implement could contribute to significant losses of maintenance resources or deteriorated maintenance service, or it could be based on a perception that the research needed to be accomplished to guide and lead a later important research effort. The “3-Year Phase” of the Master Plan has two components: (1) the “immediate action items” and (2) the proposed research projects to be worked into an orderly funding timetable such that all these projects are at least under way within the next three years. Beyond the “immediate action items,” these research needs statements were selected as a priority problem statement by three of the four breakout groups at the workshop.

Component A: Immediate Action Problem Statements

The syntheses and the two research needs projects listed above comprise the “immediate action items” for the 3-Year Phase of the Maintenance Research Master Plan.

Component B: Projects for Initiation in Years 1 through 3

No priority is implied by the order of listing of the projects herein. The full statements are listed in Appendix B.

- Application of Emerging Technologies to Highway Maintenance (A3C01-02)
- Evaluation of Sensors and Related Systems for Winter Highway Maintenance (A3C01 03/A3C09-01)
- Pavement Marking Retroflectivity for 30-Meter Geometry (A3C12-01)
- Development of Guidelines for Design, Construction and Evaluation of Polymer Concrete Overlays (A3C14-01)
- Service Life for Rehabilitation Treatments for Concrete Structures (A3C15-01)
- Long-Term Performance of Corrosion Inhibitors in Concrete Structures (A3C15-03)

CATEGORY III: 3-to-5–YEAR PHASE

Each of the research needs statements included here was selected by two of the breakout groups as a priority problem statement. While the workshop participants envisioned these research needs to be initiated as a research project in Year 3 through Year 5, if a funding research program wished to do so, any of these proposed projects could be started earlier. No priority is implied by the order of listing of the projects below. The full statements are listed in Appendix B.

- Snow and Ice Control Service Level Measures (A3C01-04)
- Develop and Disseminate Bridge Preventive Maintenance Performance Data (A3C06-01)
- Development of Guidelines for Collecting and Managing Bridge Maintenance Repair and Rehabilitation Cost Data (A3C06-02)
- Development of Guidelines for Control of Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) in Vehicles (A3C08-01)
- Standardized Equipment Classifications (A3C08-03)
- Developing a Systems Approach to Winter Highway Maintenance (A3C09-04)
- The Aging Eye and Implications on the Visual Task of Driving (A3C12-02)
- Durability in Structural Highway Concrete (A3C15-06)

CATEGORY IV: 5-to-10–YEAR PHASE

Each of the research needs statements included here was selected once (and only once) by any breakout group of the workshop as a priority problem statement. The first four problem statements in this list are assumed to have as input the results of the four syntheses proposed in Category 1 statements dealing with the state-of-practice in these four research areas. Other than that caveat, there is no order or priority within this group implied by the order in which the proposed projects are listed. The full statements are listed in Appendix B.

- Best Management Practices for Controlling Invasive Roadside Weeds[*] (A3C07-01)

[*] Note: Proposed synthesis effort in Category I is initial research project task.

- Procedures to Reduce Tire Scrap Debris on Highways* (A3C07-02)
- Pavement Markings for Cold-Weather Applications* (A3C12-04)
- Criteria for Removing Concrete and Cleaning Reinforcing Steel in Bridge Rehabilitation* (A3C15-02)
- Distillation of Polymer Modified Asphalt Emulsions (A3C05-01)
- Emulsion Treated Mix Design Procedure (A3C05-02)
- Cold Applied Transverse Crack Sealants for Asphaltic Pavements (A3C05-03)
- Field Measurement of Diffusion Coefficient in Reinforced Concrete Bridge Decks (A3C06-03)
- Field Tests for Corrosion Rates for Prestressing Tendons (A3C06-04)
- Reliability and Uncertainty: Their Role in Winter Highway Maintenance (A3C09-03)
- Bond Adhesion of Formed-in-Place Seals (A3C13-02)
- Concrete Bridge Deck Crack Repair (A3C14-02)
- Development of Guidelines for the Selection, Application, and Evaluation of Sealers for Concrete (A3C14-03)
- Condition Survey Methods for Concrete Structures: Field Validation and Calibration of Selected Methods, and Subsequent Protocol (A3C15-05)

CATEGORY V: OTHER NEEDS CONSIDERED

The following research needs statements were problems brought forward by the various committees of TRB Group 3 Section C (Maintenance), but which in the collective judgment of the workshop participants were not assigned a priority for initiation within the first ten years of the plan. No priority is intended within this set of research needs according to the order in which they are listed herein. The full statements are listed in Appendix B.

- Environmental Issues Associated with Flushing and Cleaning Bridge Decks, Joints, Drainage Components and Structural Components (A3C01-05)
- Handling of Foul and Dangerous Litter in Maintaining Rest Areas and the Roadside (A3C01-06)
- Environmental and Safety Impacts of Snow and Ice Control (A3C01-07)
- Protecting Wildlife in Transportation Corridors (A3C01-08)
- Effectiveness Analysis of Regional Native Grass Ecotypes (A3C01-09)
- Micro-Surfacing Quality Assurance (A3C05-04)
- Comparison of Bridge Management Systems (BMS) (A3C06-06)
- Slope Stabilization with Native Grasses (A3C07-03)
- Control of Storm Water Run-Off on Highway Construction Projects (A3C07-04)
- Relationship of Vegetation Management to Roadkill (A3C07-05)
- Standardization of Warning Lights for Highway Maintenance and Service Equipment (A3C08-02)
- Preventive Maintenance Program for Fleet Equipment (A3C08-04)
- Equipment Management Training (A3C08-05)
- Avoiding Buried Infrastructure (A3C08-06)
- Putting Information in Places (A3C08-07)
- Equipment Trailer Decking Material and Recycled Alternatives (A3C08-09)
- Synergistic Spatial Data Capture System for Maintenance and Construction Equipment (A3C08-10)

- Applying Total Quality Management to Winter Highway Maintenance (A3C09-02)
- Determine the Efficacy of Changing from Lead Chromate Pigmentation to Heavy Metal Free Pigments in Hot-Melt Thermoplastic Traffic Markings (A3C12-03)
- Evaluation of Pavement Joint Seat Failures (A3C13-03)
- Infrared Analysis to Detect Faulty Joint Sealant Materials (A3C13-04)
- Evaluation of New Pavement Joint Sealants and Installation Procedures (A3C13-05)
- Analytical Investigation of Adhesive Stresses in Highway Joint Seals (A3C13-06)
- Backer Rod Effects on Performance of Sealants (A3C13-07)
- Development of a Design Procedure for Control Joint Depth and Width (A3C13-08)
- Standardizing the Cleanliness and Dryness of PCC Joint Wall Conditions Prior to Seal
  Installation (A3C13-09)
- Anchoring System for Mechanical Bridge Deck Joints (A3C13-10)
- Development of Polymer Concretes for Use in Bridge Deck Overlays (A3C14-04)
- Properties of Polymer Concretes Used in Bridge Deck Overlays (A3C14-05)
- Non-Destructive Field Test to Measure Polymer Concrete Overlay Strength (A3C14-06)
- Performance Specifications for Bridge Deck Waterproofing Membrane Systems (A3C15-04)
- A Decision Model for Rehabilitating Concrete Bridges (A3C15-07)
- End-Result Specifications for Highway Concrete (A3C15-08)
- A Model Specification for Watertight Deck Joints (A3C15-09)

APPENDIX A

Group 3, Section C – Highway Maintenance Committee Titles and Scopes

A3C01: MAINTENANCE AND OPERATIONS MANAGEMENT - *Scope:* This committee is concerned with all aspects of the management of the maintenance and operations of highway transportation facilities.

A3C03: MAINTENANCE AND OPERATIONS PERSONNEL - *Scope:* This committee is concerned with the personnel policies of the various transportation organizations relative to maintenance and operations; the salaries and wages of positions in such groups; and the selection and training of maintenance and operations personnel.

A3C04: TRAFFIC SAFETY IN MAINTENANCE AND CONSTRUCTION OPERATIONS - *Scope:* This committee is concerned with optimizing traffic flow and with minimizing hazards to work crews, road users, and pedestrians in a cost-effective manner during maintenance and construction operations on streets and highways. These concerns include improved methods, procedures, materials, equipment, and devices applicable to the control of traffic in work zones and extend to the planning, design, installation, operation, maintenance, and removal of such traffic zones.

A3C05: PAVEMENT MAINTENANCE - *Scope:* This committee is concerned with factors causing deterioration and corrective measures involved in improving the surface and/or subsurface condition of degraded or slippery pavements and shoulders.

A3C06: STRUCTURES MAINTENANCE AND MANAGEMENT - *Scope:* This committee is concerned with failures and corrective methods and materials employed in strengthening, rehabilitating, and repairing bridges, box culverts, tunnels, retaining walls, and other structures of a similar or related nature. This committee is also concerned with the management of such structures, including maintenance, rehabilitation, and replacement planning.

A3C07: ROADSIDE MAINTENANCE - *Scope:* This committee is concerned with roadside maintenance, methods, materials, and equipment, exclusive of traffic control devices, leading to a realistic balance between aesthetics, safety, services, conservation of capital, preservation of the original investment, and with guidance for planners, designers, and construction personnel.

A3C08: MAINTENANCE EQUIPMENT - *Scope:* This committee is concerned with selection, repair, replacement, development, employment, and management of maintenance equipment.

A3C09: WINTER MAINTENANCE - *Scope:* This committee is concerned with all aspects of snow and ice removal and fog control, including storm warnings; snow accumulation and drift prevention; organization for snow and ice removal; snow and ice removal equipment; plowing and disposal procedures; drainage of melting snow and ice; pavement heating systems; materials for dispersing fog or removing or disbanding snow and ice; fundamental aspects of fog control, ice adhesion, and heat transfer as they influence operation and control of traffic under adverse winter conditions.

A3C12: SIGNING AND MARKING MATERIALS - *Scope:* This committee is concerned with all factors affecting the choice, use and performance of paints, plastics, and optical elements used in retroreflective materials and devices for delineation and signing.

A3C13: SEALANTS AND FILLERS FOR JOINTS AND CRACKS - *Scope:* This committee is concerned with all of the factors which affect the use and performance of sealants and fillers for joints and cracks used in the construction, maintenance, and rehabilitation of transportation facilities.

A3C14: POLYMER CONCRETES, ADHESIVES, AND SEALERS - *Scope:* This committee is concerned with the investigation of polymer concrete, adhesives, and sealers as they relate to the construction and rehabilitation of transportation facilities. Acrylics, epoxies, polyesters, urethanes, latex formulations, and other polymeric materials together with their modifications are included. Excluded from consideration are portland cement, asphalt, and tar, except where they are utilized as modifiers for polymerization products.

A3C15: CORROSION - *Scope:* This committee is concerned with all factors which influence corrosion of metals, with means for mitigation of corrosion of metals, and with means for dissemination of information about prevention and control of corrosion of metals.

APPENDIX B

Highway Maintenance Research Problem Statements Listed by TRB Committee

COMMITTEE A3C01 – MAINTENANCE AND OPERATIONS MANAGEMENT

A3C01-01: Asset Management-Framework for Allocating Resources Among Maintenance Assets and Services

Problem: One of the most important problems transportation agencies face as they become increasingly responsive to their customers is making informed choices and tradeoffs regarding maintenance expenditures for pavements, bridges, and other maintenance assets and services. Although, states, local governments, and toll authorities have invested enormous amounts of funds in legacy systems and separate data repositories for pavement, bridge, and maintenance management, a number of critical problems must be addressed to enhance decision making. First, a practical framework is lacking to facilitate choices and tradeoffs. Second, existing data useful for making choices and tradeoffs is not easily accessible in most agencies because of the stovepipe nature of their databases. Third, additional data of the right type for decision making are required as states transition from focusing on outputs and levels of service, to customer oriented outcomes and to the value customers receive.

Objective: The overall objective of the research project would be to develop and test a framework for maintenance decision making that would permit the analysis of choices and tradeoffs and improve resource allocation among maintenance expenditures for bridges, pavements, and maintenance services and assets.

Key Words: GASB, asset management.

Related Work: NCHRP 20-24(11), Asset Management Guidance for Transportation Agencies.

Urgency/Priority: State DOTs are being asked to comply with new accounting standards from the Government Accounting Standards Board. These standards have implications for all of these agencies in how they prioritize and account for their maintenance expenditures. This research may be a key part of complying with these new standards.

Cost: $375,000.

User Community: AASHTO member organizations.

Effectiveness: Give a best estimate of the societal impacts of this research. If possible, describe the relevant measures of effectiveness.

A3C01-02: Application of Emerging Technologies to Highway Maintenance

Problem: Technology is changing the business of maintenance management. Advances are being made in technology that may be applied to maintenance including physical technologies as well as information technology. Technologies currently being deployed include real time data on pavement and weather conditions, advanced vehicles to enhance productivity and advanced patching and crack sealing machinery. Many more technological advances are on the horizon that have the potential to greatly enhance maintenance management.

Objective: Research is needed to identify and accelerate the use of emerging technologies in maintenance methods, equipment, materials, diagnostic procedures, and asset performance.

Key Words: RWIS, GPS, Internet, infrastructure performance, GIS, laptop computers.

Related Work: Iowa, Minnesota & Michigan Advanced Maintenance Concept Vehicle, SHRP Program, SICOP.

Urgency/Priority: This research has high priority. To date there has been no comprehensive look at emerging technologies and their overall applicability for maintenance.

Cost: $200,000.

User Community: AASHTO & APWA.

Implementation: This project will set the tone and provide direction for future technology applications.

A3C01-03/A3C09-01: Evaluation of Sensors and Related Systems for Winter Maintenance

Problem: Significant experimentation has been undertaken in recent years to evaluate technology to sense roadway conditions through roadway weather information systems (RWIS) and through "concept maintenance vehicles" to sense the application of snow and ice control treatments while simultaneously dynamically sensing the road surface to tire interface conditions. What is lacking is an integrated analysis of the accuracy of these various sensing systems to be able to calibrate the snow and ice control measures taken to the effectiveness of the results. For instance, it is suspected that the RWIS road sensor instrumentation may not retain proper calibration to actual roadway surface conditions as various anti-icing and deicing chemicals are applied to the roadway surface. Likewise, the calibration of the sensors dynamically controlling the rate of application of various chemicals in pre-wetting processes and anti-icing processes needs to be related to an accurate measurement of the existing roadway conditions before application, immediately after application, and short-term predicted road surface conditions after application. Finally, these various data need to be integrated and presented in such a way that the

analysis can produce real-time decisions or adjustments to snow and ice control treatments.

Objectives: The various objectives of this proposed project include:

1. Assess and evaluate the extent of any lack of accuracy between RWIS instrumentation estimates of roadway surface conditions and actual conditions. Develop a corrective solution, as may be needed, so that RWIS instrumentation provides an accurate report of actual field roadway surface conditions.
2. Assess and evaluate the extent of any lack of accuracy between on-board maintenance vehicle sensors dynamically measuring the application of snow and ice control treatments and dynamically measuring roadway surface conditions. Develop a corrective solution, as may be needed, so that the on-board vehicle sensor dynamic measurements provide an accurate report of actual treatment and surface conditions.
3. Correlate the resultant accuracy-corrected RWIS report of actual field roadway surface conditions to the corrected on-vehicle dynamic measurement of roadway surface conditions.
4. Develop a real-time decision process for application of snow and ice control treatments based on integrated data streams from RWIS and on-vehicle sensors.
5. If new sensing devices are required to achieve real-time integration of RWIS and on-vehicle data integration, prepare a system design for such sensors to achieve real-time integration.

Key Words: RWIS, road sensors, on-vehicle sensors, anti-icing, deicing, integrated decision data.

Related Work: Concept maintenance vehicle testing in Minnesota, Iowa, and Michigan.

Urgency/Priority: This proposed project is deemed necessary to bring user expectations of winter maintenance level of service to engineering management control of the application of snow and ice control.

Duration/Cost: It is anticipated this proposed research would require 3 years and approximately $350,000.

Implementation: Shared data and correlations among states and local agencies having RWIS installations will lead to increased accuracy and better winter maintenance planning and management. Cooperative state implementation and evaluation projects on correlation of on-board sensor data with RWIS data will lead to equipment production being regularly available through commercial sources.

Effectiveness: Improved accuracy of data, improved reliability of measurements related to maintenance levels of service, and integration of roadway surface data with snow and ice control treatment application data will lead to reduced chemical application. This will reduce winter maintenance costs and increase environmental quality.

A3C01-04: Snow and Ice Control Service Level Measures

Problem: Many state DOTs and local agencies are implementing quality assurance programs for highway maintenance as developed in NCHRP 14-12, Highway Maintenance Quality Assurance. A basic component of the quality assurance process is the measurement of program performance. Typically, field condition measurements such as pavement, drainage, traffic services, etc., are randomly taken at specified intervals. These conditions are "static" in that they normally do not show changes from one day to the next. Measurement of snow and ice service levels is much more difficult because of the nature and duration of storms. Several states (e.g., Washington, Minnesota, California) are attempting to make such service level measures. Research is needed to develop a more formal process for winter maintenance service level measurements to complete the overall quality assurance program for those states with significant winter maintenance programs.

Objective: Develop performance measures for winter maintenance and a statistically valid process for taking service level measures.

Key Words: Customer feedback, data collection and analysis.

Related Work: NCHRP Project 14-12, Highway Maintenance Quality Assurance.

Urgency/Priority: The research is of high urgency and priority from a timeliness standpoint. It is a critical part of a complete maintenance quality assurance process.

Cost: $150,000.

User Community: AASHTO, SICOP, Winter Maintenance Policy Coordinating Committee, and APWA.

Implementation: The research results will be put into immediate practice as a part of the overall maintenance quality assurance programs.

Effectiveness: Experience with the Maintenance Accountability Process (MAP) in Washington State and similar programs in other states has demonstrated policy maker and budget support is more likely to be provided for those programs that can demonstrate such accountability.

A3C01-05: Environmental Issues Associated with Flushing and Cleaning Bridge Decks, Joints, Drainage Components and Structural Components

Problem: Highway and street maintenance agencies routinely clean bridges, particularly after winter operations are complete, to flush deicers and abrasives from the bridge decks and to open expansion joints and structural and drainage components. Literature searches through the TRIS system resulted in a number of papers documenting the benefits of cleaning and flushing but were related to increased bridge life. Few papers were found

which were related to environmental issues: wash water and sediment disposal, air pollution.

It is probable that failure to control dust, wash water, and sediment results in environmental pollution and consequently state, federal, and/or local regulations are not being met.

Objective: Develop a synthesis to identify the major environmental issues relating to cleaning and flushing of bridges and to identify the best management practices relating to control and proper disposal of dust, sweepings, and wash water resultant from bridge cleaning activity. The synthesis product should be in the form of a handbook for use by field operations managers and line supervisors.

Key Words: Bridges, cleaning, environmental, regulations.

Related Work: It is not known if related work is taking place or has recently been completed.

Urgency/Priority: Bridge cleaning is occurring on a routine basis throughout the country. Environmental violation conditions are likely to be also occurring. With increased emphasis on storm water regulations (NPDES permits) and the listing of species of salmon as endangered on the West Coast, the need for the synthesis will become more urgent.

Cost: $50,000 over six months.

User Community: Unknown.

Implementation: FHWA through the LTAP process could make local government aware of the synthesis and handbook. AASHTO, through the bridge committee, could provide the information to the states' bridge engineers.

Effectiveness: The development of best management practices should, over time, lead to improved water and air quality.

A3C01-06: Handling of Foul and Dangerous Litter in Maintenance Rest Areas and Roadsides

Problem: The content of litter and refuse at highway safety rest areas includes difficult to pick up and dispose of items such as tires, bio-hazard waste, broken glass, and waste oil material. This material can be difficult to handle and disposal costs may be high.

Objective: Research is needed to review state agency policies, guidelines, and procedures to define what has been done to expedite the safe handling and disposal of unsanitary, hazardous, or otherwise problematic waste.

Related Work: Many states have conducted research on litter volume and content. Litter and disposal issues are often shared with state Departments of Environmental Quality or Ecology as well as local health authorities.

Urgency/Priority: The cost of the problem is unknown; however, there is a potential for injury or illness. Therefore any opportunity for improvement in this aspect of highway maintenance and operations would be in the interest of public protection and health.

Cost: $100,000 to develop, distribute, process, and analyze a national survey.

User Community: The results of this effort would be of use to all transportation organizations.

Implementation: Once findings were studied, a guidance document would need to be prepared for distribution throughout the states. It would then be up to individual agencies to adapt recommendations to local constraints.

Effectiveness: If the end result of this information and succeeding recommendations is improvement in protecting the public health and safety, as well as providing help in answering difficult questions in handling and disposal, then there is potential for societal and highway operational benefits.

A3C01-07: Environmental and Safety Impacts of Snow and Ice Control

Problem: Approximately $1.5 billion is expended annually in the United States on snow and ice control. One-third of the cost, approximately $500 million, is expended on materials, primarily salt. Effective snow and ice control is therefore a significant expense and major challenge for states and local governments in the 38 snowbelt states. Inadequate application of chemicals and abrasives can result in loss of mobility, increase in injury, death, and property damage from accidents and a major negative impact on an area's economy. Overapplication results in needless cost and undesirable effects on air and water quality and degradation of infrastructure and personal property.

While anti-icing and deicing chemicals have been used in winter maintenance for many years, the optimal application rates of these materials and chemicals for different weather conditions, temperatures, road surfaces, and desired level of surface have not been quantified.

Objective: Research would focus on 1) best methods for determining the most appropriate snow and ice control response; 2) existing and potential equipment improvements including better liquid, dry and pre-wetted chemical delivery patterning, more precisely controlled application rates, GIS/GPS adjusted rates related to pavement types, current and forecasted road conditions with real time thermal and friction readings, and methods for the rapid changing of the chemical and abrasive mix being delivered; 3) results of state, national, and international research, i.e., SHRP and FHWA test and evaluation based on snow and ice control programs for better storm management practices and reducing the need for chemical and material application rates; 4) SHRP snow fence research—the Kansas City, Missouri, airport experience with tall native grass

and Great Plains shelter belt research for reducing mechanical and chemical snow control costs; and 5) relationship of winter maintenance to traffic safety. Information sources for the study would include literature search using TRIS and other domestic and international databases. The contractor will evaluate technology and assess costs and value benefits. Contractor will provide fact sheets summarizing the important elements of the research and a video of approximately 20 minutes' duration explaining the results and benefits of improved snow and ice control practices.

Key Words: Snow, ice, methods, effective, equipment, improvements, optimal.

Related Work: SICOP is developing implementation of new and ice technologies.

Urgency/Priority: Snow and ice control represents the largest proportion of snowbelt maintenance budgets and effort. This study on developing quantifiable effective practices would reduce costs and minimize environmental problems.

Cost: $225,000 over 18 months.

User Community: AASHTO and FHWA.

Implementation: AASHTO Committee on Winter Maintenance could serve as the springboard for information product distribution.

Effectiveness: Snow and ice control costs should be reduced with the implementation of the best management practices developed by this research. Environmental benefits would be achieved.

A3C01-08: Protecting Wildlife in Transportation Corridors

Problem: Designing and maintaining roadsides and other transportation right-of-ways to reduce animal mortality through the preservation and development of habitat, with riparian corridors, longitudinal continuity, and channeled lateral crossings, has not been widely practiced in the U.S. In addition, this will address issues of safety, environmental resource protection, and Endangered Species Act (ESA) compliance.

Objective: Identify best management practices for roadside maintenance activities, which would preserve and improve wildlife habitat and mobility without compromising standards for highway safety. Prepare a report or guide for use by designers and maintenance managers.

Key Words: Animals, mortality, reduction, safety.

Related Work: This concept has been developed in Europe. In addition, U.S. Forest Service, Pacific Northwest Research Station, and the WSDOT entered into a cooperative agreement to conduct research on the effects of the Interstate 90 corridor on wildlife movement. The work started in January 1998 and was completed in December 1999; the report title is "I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment." The primary

objectives of this project were to 1) determine the nature of highway and road barrier effects on animal movement and populations, and 2) develop a landscape-scale methodology for integrating wildlife conservation and human safety in transportation corridors (Lehmkuhl 1997). This report reviews the findings of this project and presents strategies for maintaining and enhancing landscape permeability for wildlife in the vicinity of I-90 near Snoqualmie Pass. Part of this study included an extensive bibliography (approximately 1,200 citations) on the interaction of wildlife and roadways. The bibliography is posted on the Wenatchee Forestry Sciences Lab web site (www.fs.fed.us/pnw/wenlab/research/projects/wildlife). A PNW Research Station General Technical Report is in preparation based on this material and will be submitted for publication in 2000.

Urgency/Priority: High. Collisions with wildlife constitute a significant safety hazard to the traveling public. Data collected by WSDOT shows that from 1996 through February 1999 a total of 36,803 deer and elk were reported as killed statewide. It is estimated that vehicle-animal collisions in Washington state cost the public over $6 million annually in vehicle damages alone.

The USFWS, USFS, EPA, and others have been pressing WSDOT to address habitat connectivity to a greater extent in our projects. This is also a significant issue for protecting wildlife since roads can be a major barrier to habitat connectivity and a source of mortality for many species including threatened and endangered species. This has been identified as a deficiency in revisions to the WTP and it relates to ESA compliance for many terrestrial species, such as the Canada lynx, which has recently been federally listed as threatened.

This research will identify and prioritize best management practices that will be used by maintenance managers to decrease the number of animal collisions and increase connectivity zones for wildlife movement within highway corridors.

Cost: $200,000.

User Community: The results of this effort would be of use to all transportation organizations.

Implementation: The primary market for the report or guide will be transportation agencies, and possibly resource and regulatory agencies. The principal product of the research will be a report or guide on best management practices for roadside maintenance activities, which would preserve and improve wildlife corridors and reduce animal collisions. The implementation plan may include distributing copies of the report to member agencies of AASHTO, the National Association of Regional Councils, and the Association of Metropolitan Planning Organizations. The memberships of these organizations are primary users and the critical mass for the report/guide market. Information on the report/guide and where it can be obtained should be posted on the websites and in periodic publications of the USDOT and the organizations noted above. Several organizations have active committee structures with topical interest, such as the AASHTO Standing Committee on the Environment and Transportation Research Board committees. Many of the members are potential guide book users, and the research team should interact with the committees. Presentations on this project during the research and at its conclusion are highly recommended.

- Improving habitat connectivity
- Decreasing animal collisions
- Maximizing habitat improvements

A range of options should be provided to achieve the prescribed outcome based on conditions in the field. The report/guide should clearly recognize the difficulties encountered in the field when implementing BMPs. Conditions vary dramatically from site to site, or from locations, within each state, based on a myriad of factors:

- Spoils/geological conditions
- Stream/surface water hydrology
- Groundwater conditions
- Presence of structures
- Vegetation
- Resource availability
- Regulatory requirements (i.e., permit requirements)
- Legal requirements (such as safety standards, regulations)
- Terrain
- Space available in right-of-way

The menu of options provided in the National BMP Standards allows crew supervisors, design engineers, and biologists the flexibility to select the most efficient BMPs for each individual site. This can be best measured by a reduction in animal collisions along with an increase in species detected in camera surveys.

A3C01-09: Effectiveness Analysis of Regional Native Grass Ecotypes

Problem: The 1994 President's Executive Memorandum called for the use of native grass and forbs on all federally funded projects as much as practicable. Regional native plants are to be used by all federal agencies as well. Thus far, state highway agencies have had mixed success and some have decided that native plants are not always practicable. The scientific community suggests that using regional ecotypes will enhance the success of roadside projects and long-term vegetation management efforts. The seed industry awaits clear direction on what type of seed they should be investing in. In the meantime, industry cannot satisfy the demand for native grass seed. Native seed sources could be expanded and highway planting could be more successful, if the range of plant ecotypes were defined. This project would provide data to assess the potential benefits and costs savings if native ecotypes were planted and properly managed over time.

Objective: Establish and monitor test plots in locations around the country, ranging north/south and east/west. Test plots would be established with a species of grass such as Little Bluestem, which has ecotypical variation throughout the country. Monitor the plots over a period of time and document any measurable difference in management cost or vegetative performance.

Key Words: Plant establishment is the site and soil preparation, seed, fertilization, and mulch application. Vegetation management is the maintenance applied to roadside plants

and their habitat to fulfill the highway's operational and environmental objectives. Erosion control is one of the initial functions grass stands provide in site restoration efforts.

Related Work: Many states have implemented test plots for native vegetation. These projects are often developed in cooperation with state institutions for higher learning (cooperative extension services). The nursery industry is another major customer for roadside restoration with native shrubs, trees, and ground covers, with an interest in the overall need to supply native plant material.

Urgency/Priority: Availability of the seed necessary to comply with the Executive Memorandum is not plentiful enough for all federal agencies and state highway agencies. Once we are able to define the range that various ecotypes can successfully cover, the seed industry will respond with the supplies of native grass seed now in short supply. In 1996 for example, the Montana SHA expressed concern because the Forest Service had purchased the West's entire native grass seed supply, for replanting after forest fires. The SHA was not able to comply with the intent of the Executive Memorandum in this case. Seed producers will not be willing to risk investment in native seed production until it is confirmed that the use of native grass species is the best alternative for roadside and other site restoration and erosion control.

Cost: Approximately $25,000 per 1-acre plot with one plot in each of the ten natural regions of the country for a total of $250,000 for initial implementation. The cost of monitoring the sites and organizing and analyzing the data for 5 years following initial establishment would be $200,000. The total project cost would be $450,000.

User Community: The results of this effort would be useful to all transportation organizations.

Implementation: It will be critical to the success of this research to carefully select, prepare, and manage the set of test plots with some degree of consistency. Assuming success for the majority of test sites, the research results could be used to develop typical specifications and seed sources for transportation agencies within the regions to adopt and require for construction and maintenance applications.

Effectiveness: The benefits from using native plants are difficult to measure. Much of the American landscape has already been cultivated and planted with non-native species. However, in terms of the President's Executive Memorandum, it is very important that local interests protect their regionally indigenous plant and animal populations. Measurement of this research in terms of highway maintenance and operations comes down to functional and cost benefit in erosion control and competition with undesirable, non-native, invasive plants.

COMMITTEE A3C05 - PAVEMENT MAINTENANCE

A3C05-01: Distillation of Polymer Modified Asphalt Emulsions

Problem: Present distillation methods for obtaining residues from asphalt emulsions that are polymer modified can result in residue that does not represent material that is on the roadway. Degradation of the residue can result even when using low recovery temperatures such as 260°C.

Objective: When completed this work should show the following:

- Statistically valid test data.
- Test data that includes results from currently existing distillation procedures and any new or modified procedures.
- Test data that includes currently specified residue procedures and the new SHRP procedures. The SHRP procedures should not include any conditioning after distillation of the emulsified asphalt.
- Recommendations for implementation of this work, including test procedures drafted in AASHTO format.

Current Activities: A review of the existing literature needs to be conducted to reduce any duplication of effort. For reference, some work is currently being done by the Emulsion Committee of the Pacific Coast User/Producer Conference.

Urgency: A substantial amount of emulsified asphalt is used throughout the world each day. The use of polymer modified products including emulsified asphalt is increasing. The use of test procedures, such as for distillation, that do not reflect the residue characteristics of the asphalt is compromising the ability to work with the materials and to accurately predict the in-place quality of the emulsion residue.

Cost/Duration: The cost of this work is estimated at $250,000 and could take as long as 2 years.

A3C05-02: Emulsion Treated Mix Design Procedure

Problem: The current literature for emulsion treated mix designs does not adequately furnish the specific step-by-step procedures needed. Several publications are available but they do not address the specific methodology of a thorough laboratory design procedure. Most agencies either modify existing procedures such as Marshall or incorporate their own methods that are usually not performance related. The increased use of lime, cement, or fly ash in the cold recycle process further justifies the need for detailed mix design procedures.

Objective: The procedure developed should be a detailed step-by-step design that predicts the performance of the mixture. Specific procedures should be addressed in the design:

- Sample preparation: The emulsions, aggregate, water, and additives can be mixed with equipment that duplicates the process used during actual production.
- Curing procedure: A detailed procedure for curing the prepared mixture shall be established that is related to field production and conditions.
- Performance: Develop physical testing procedures that predict the long-term performance of the mixture.

Costs: Phase I, which includes a literature search, should be done first to take advantage of existing research and techniques that could be incorporated in the research in order to meet the desired objectives at $30,000. Phase II includes basic research, personnel, equipment, and mix design procedure with approximately 2 years to complete at $250,000. Phase III includes implementation, selected projects, ruggedness, and round robin testing with approximately 1 year to complete at $200,000.

Implementation: A detailed plan for implementation would be prepared. This plan would include but not be limited to trial projects, field validation and design procedures, and test methods in ASTM format. Upon completion of the work, ISSA, AEMA, AI, FHWA and FPRMR joint sponsored seminars, workshops, society papers, and presentations can be planned to train and disseminate information.

A3C05-03: Cold Applied Transverse Crack Sealants for Asphaltic Pavements

Problem: A majority of transverse crack sealing materials used for routine maintenance of asphalt pavements require the use of a double boiler melter. Boilers are fairly expensive and working with hot sealants can be hazardous. If “equivalent” cold applied materials, which do not require special equipment, could be substituted it would reduce start-up costs and make for a safer operation.

Objectives: Develop or identify cost-effective, environmentally safe cold applied crack sealants for asphaltic pavements which perform as well as or better than hot applied materials. A durable, low cost, cold applied sealant would increase the likelihood asphaltic surfaced pavements would be properly maintained. The skill level of maintenance workers used to make the application could be lowered since the use of specialized equipment would not be necessary. Documented research clearly indicates properly sealed roads last longer and over the long run ride better. The measure of effectiveness would be public perception of better roads at overall lower cost. Effective marketing by producers drawing support from government research efforts would be an effective method of implementation.

Funding: The estimated cost of this effort is $100,000.

Current Activities: Crack-sealing research has tended to concentrate on hot applied materials with some emphasis on emulsions and silicone sealants. However, no specific effort aimed at developing or identifying cold applied materials is evident.

Urgency: High priority, since crack sealing is a widespread maintenance activity involving millions of dollars of work. If durable low cost, cold applied sealants were available they would likely be implemented within a relatively short period.

A3C05-04: Micro-Surfacing Quality Assurance

Problem: Many agencies are currently using micro-surfacing as a maintenance treatment for pavement deficiencies. Currently, there are no standard methods available to complete quality assurance checks during the treatment application. Field personnel must rely on previous experience or contractor expertise. The standard specifications are vague concerning the types of checks that would be useful.

Objectives: Develop standard quality assurance procedures for micro-surfacing treatment application to ensure that the treatments are applied correctly. A set of quality assurance guidelines including checklists for materials, equipment, material tests, treatment application process checks, and post application checks should be developed. A training program should be prepared to allow agencies to train their inspectors on the quality assurance process. This process should improve the service life of micro-surfacing treatments.

User Community: The audience for this work includes members of AASHTO, the FHWA, and local agency organizations such as APWA and RTAP.

Funding: The estimated cost of this research effort is $150,000.

Current Activities: No major work is known to be under way.

Urgency: Hundreds of millions of dollars are spent on surface seals each year in the U.S. More of that market is going to micro-surfacing each year. It is imperative that those purchasing this material have the proper quality assurance techniques to ensure the treatment is placed properly.

COMMITTEE A3C06 – STRUCTURES MAINTENANCE AND MANAGEMENT

A3C06-01: Develop and Disseminate Bridge Preventive Maintenance Performance Data

Problem: Ideally, bridges should be maintained in good condition throughout their service life. Research has shown that this is the most cost-effective strategy for a transportation agency to adopt. The work that is performed to keep a bridge in good condition is called preventive maintenance (PM). Since bridges are complex structures, with many parts composed of different materials, there are many different PM procedures that are recommended. When new methods or products are developed, it may take several years of use to evaluate their effectiveness. It is very difficult to compare alternative methods and products. Rates and intervals of application are also usually

determined by trial and error. Other factors such as traffic, climate, and age of the structure are also important considerations.

In many states, bridge maintenance crews experiment independently to develop PM strategy for their structures. Depending on the organization, crews within the same state don't always communicate their successes or failures. The information is rarely communicated across state boundaries. Bridge management systems (BMS) have the potential to help refine PM strategy for an agency. If properly programmed, they might collect cost and performance data to help compare the various PM alternatives. Realistically, BMS development and implementation is many years away from providing reliable PM strategy, assuming agencies collect the appropriate data.

Objective: Develop and implement an ongoing, user-friendly mechanism to collect and disseminate unbiased performance data related to PM of bridge components. Keep this information up to date and make it available electronically to state DOTs.

Related Work: The FHWA Bridge Maintenance Training Course has been presented nationwide. Along with routine maintenance and repair, it includes basic information on the importance of PM and step-by-step instructions for performing basic procedures. The attendees have expressed much interest in performance criteria for PM alternatives. The instructors transmit some of this information informally between groups. A part of this work would be to collect relevant information from other research projects.

Urgency/Priority: The proposed work is very timely since transportation agencies are placing more emphasis on PM, including directing significant funding to this effort. They are often experimenting with products and procedures to protect bridge elements. There is significant potential benefit in identifying other agencies that have used the product. There are obviously many factors that influence performance. However, the more information available, the better the chances of success. The potential benefit is that limited funding can be used more effectively and the service life of the bridge is extended. The results of this research can be used immediately.

Cost: Estimated at $300,000.

A3C06-02: Development of Guidelines for Collecting and Managing Bridge Maintenance Repair and Rehabilitation Cost Data

Problem: The United States has nearly 600,000 bridges, which require periodic maintenance, repair, and rehabilitation in order to provide safe and cost-effective service. The need for increased, stable funding for bridge maintenance is well known in state transportation agencies, and often depends on management capability to prove that bridge maintenance has value in effectively holding down the life cycle costs. This capability is currently limited by the difficulty in identifying and collecting maintenance repair and rehabilitation costs that are compatible with planning activities and bridge management systems.

Bridge management systems (BMS) such as AASHTO's Pontis and Bridgit systems have demonstrated the usefulness of cost data and have standardized a means of expressing these data for planning purposes. However, few states have yet worked out

how to generate the needed data. Most states collect relevant data in the form of pay or bid items, which do not directly correspond to bridge elements.

The proposed research would address available data resources (maintenance and contract management systems) and planning applications (bridge management systems). It will describe BMS requirements for accuracy, precision, timeliness, and quality of cost data. It will conduct a detailed domestic and international survey of transportation agencies to find, describe, and evaluate relevant methodologies under development and put into practice for converting pay item data and other available agency data into the cost factors required in a BMS. These techniques are likely to vary by type of bridge element and type of work.

This investigation also will review indirect cost factors, such as traffic control, mobilization, and project engineering, and functional improvement and replacement costs. For pay items where sufficient data can be found, the research will show how these data vary with agency characteristics, to help other agencies that may wish to use the data for planning purposes or compare them with their own costs. For agencies planning to develop new maintenance and/or contract management systems, the research will provide design guidance to help ensure that the new systems will satisfy the data needs of bridge management systems.

Objective: The research will produce a user-friendly manual with guidelines for developing pertinent data items and cost factors needed in a BMS, including the design of data collection methods and interfaces with existing maintenance and contract management systems. The guidelines will provide methodologies for transforming cost data in forms commonly found in transportation agencies, into a form usable in a bridge life cycle cost analysis. These methodologies and implementation strategies will help the states to significantly enhance the usefulness and credibility of their bridge management systems. The work will not be tied specifically to any existing BMS: the manual should have direct utility for any agency that forecasts bridge needs from inventory and inspection data, especially element-level data.

Key Words (other than those in the title): Unit costs, maintenance management systems, contract management systems life cycle costs, needs identification, cost estimation.

Related Work: This work would build on the results of NCHRP Synthesis 227, Collecting and Managing Cost Data for Bridge Management Systems (1996), which specifically recommended the development of a set of guidelines for collecting and managing cost data.

A 1996 FHWA study by Clemson University attempted to collect available element-level cost data from the states implementing Pontis, and confirmed the NCHRP Synthesis 227 findings that most states have a great deal of difficulty developing this information. States attempting to implement the Clemson results encountered difficulties because of large differences in cost experience among the states. For this reason, this research proposal places more emphasis on methodologies than on the collection of actual cost data, so each state can implement the methodology and develop more satisfactory cost factors from its own data.

NCHRP Report 363, The Role of Highway Maintenance in Integrated Management Systems (1994), showed that most states do collect relevant cost data, but not in a form usable in a BMS. Certain international BMS development efforts, notably

Ontario, Denmark, Finland, and Switzerland, have had to address this same problem and have developed techniques that may be applicable in the U.S. with suitable transformations.

Urgency/Priority: The proposed work is very timely in the ongoing effort to implement bridge management systems in the United States. Consistency and accuracy of cost data is very important to the credibility of maintenance and capital programs. Improving this accuracy is essential to protect the value of the investments most states make in their bridges and is now widely regarded as the highest-priority research issue for bridge management systems.

User Community: This research is relevant to the roles of the State Department, FHWA, AASHTO, and NCHRP.

Cost: Estimated at $300,000.

A3C06-03: Field Measurement of Diffusion Coefficient in Reinforced Concrete Bridge Decks

Problem: The diffusion of chloride ions into concrete decks initiates corrosion of reinforcing steel. Decks with high diffusion coefficient are vulnerable. Decks with low diffusion coefficient can offer protection to rebars and longer service life.

Objectives: Differences in diffusion coefficients are important information for planning deck replacements. Diffusion coefficient, and the vulnerability associated with chloride ion diffusion, can be known before any deterioration has taken place. An ability to measure diffusion coefficients on site will identify vulnerable decks.

Current Activities: SHRP research projects have investigated methods for field measurement of water permeability and air permeability of concrete. Permeability is related to diffusion coefficient, but there is not sufficient work to form a general empirical relation between permeability and diffusion coefficient.

Urgency: The research will provide bridge engineers with a quantitative measure of the vulnerability of decks to an important mechanism of deterioration. Substantial benefits in planning replacements of decks will be gained. These benefits include lower user costs because of efficient planning and coordination of projects to achieve shorter delays and fewer detours. This research also will lead to field methods for quality assurance in new construction of decks to keep diffusion coefficients low.

Cost/Duration: The research requires lab tests of standard specimens to calibrate an empirical relation, followed by field testing on bridge decks to confirm the performance of the test. A research program is proposed in two phases: first lab testing and then field use. Costs are about $200,000 for lab work and $100,000 for field testing with 24 months for lab work and 12 months for field demonstration.

A3C06-04: Field Test for Corrosion Rates for Prestressing Tendons

Problem: Corrosion in prestressing steel is a threat to safety of bridges. Tests such as half-cell potential for corrosion activity and linear polarization for corrosion rate have been developed and applied to nonprestressed reinforcing steel. The experience in the application of these methods to prestressed beams is that the methods respond to the corrosion activity rebars, but do not separately discern the corrosion activity or rates for prestressing steel.

Objective: Test methods are needed to assess tendons directly to determine corrosion activity and corrosion rates.

Current Activities: SHRP research had worked with linear polarization methods, and half-cell methods for nonprestressed reinforcement. Applications of these methods to prestressed bridges have not been successful in defining the corrosion activity of tendons.

Urgency: The research is urgent. There is a severe lack of methods for early assessment of corrosion of tendons. At present, tendon corrosion is discovered only after it is severe enough to spall the concrete cover. This is far too late. Sensitive and reliable methods are needed for early detection of corrosion activity.

Cost/Duration: This is a basic technology development effort, and could cost $50,000 for a small exploratory phase and $500,000 for full development and demonstration, with 12 months for exploratory work and 24 months for full development and demonstration.

A3C06-05: Procedures for Condition Assessment of Prestressed Concrete Bridges

Problem: Serious damage in prestressed concrete members is apparent from the cracking and spalling that occur. But early detection of deterioration is usually not achieved, though many contributing factors such as concrete quality, cover, and service environment are known and could be incorporated in an assessment of the probability of deterioration.

Objectives: A synthesis is needed of procedures for inspection of prestressed concrete members and the use of electrical and chemical tests to evaluate the vulnerability of prestressed concrete members. A synthesis will review recent developments and ongoing research in measurement of prestress force, corrosion activity, etc. The synthesis will guide further development of a standard practice of evaluation of prestressed concrete members.

Current Activities: Investigations of prestressed bridges employ many standard procedures including visual inspection, sounding, and chemical and electrical tests. Guidance is needed on the integration of multiple inputs to condition assessment and to the assessment of vulnerability of prestressed members.

Urgency: The research is urgent. Informed inspection and assessment of pre-stressed members are essential to the safe maintenance of the large and aging population of pre-stressed bridges in service in the United States.

Cost/Duration: $150,000 at 12 months.

A3C06-06: Comparison of Bridge Management Systems (BMS)

Problem: PONTIS bridge management system was developed under a FHWA program and BRIDGIT under an NCHRP project, and a number of states, including Pennsylvania, New York, and Indiana, are advancing their own unique approach. Other countries, members of OECD, are also making or have made significant progress in this field. Within the United States currently the question often arises about what the benefits of a given bridge management system are, how its application changes bridge management, and which system is best suited for a given bridge network.

Objective: The objective of the proposed research project is to compare a number of bridge management systems by applying them to the same sample of selected bridges and obtaining results within the framework of each BMS. The results will greatly advance the understanding of bridge managers nationwide on the capabilities and use of BMS. Decisions on the suitability of various BMS for given conditions will be facilitated. An understanding will be gained on the needed improvements in the quality and scope of input data from bridge inspections and output data for decision making.

Key Words: Bridge, comparison, management, system.

Related Work: PONTIS and BRIDGIT have been recently developed and are still in stages of enhancement and implementation. The project for developing life-cycle cost analysis software compatible with the above programs is in progress. States developing their own BMS are at various stages of implementation. Representatives of other countries, members of OECD, have approached certain bridge managers with their developed programs for possible purchase.

Urgency/Priority: The proposed work will provide findings of immediate use to all state and local bridge managers. Furthermore, it would serve as a point of reference for a new and higher level of understanding in the efforts to introduce nationally acceptable levels of bridge management. If an assessment of overseas products is included, the project would have a contribution worldwide and might gain some support by OECD.

Cost: The project will require selecting a number of sample bridges and the cost will depend on that number, as well as on the number of BMS considered. The bridges would have to be inspected according to the varied requirements of each of the compared BMS. Consequently the team conducting the work will need to become familiar with all of the compared BMS and apply them at every level. A comparison with other projects of comparable magnitude suggests a minimum cost of $300,000–$500,000.

User Community: The results of this effort would be useful to FHWA, state and local bridge owners, and AASHTO. The findings will be of help to any bridge owners who have to select or enhance their BMS. FHWA would gain a better understanding of the bridge management conditions in the various states.

Effectiveness: The effective management of the nation's bridges is essential to the national development. The question of mandating or recommending a BMS for all bridge owners has been considered for a number of years and is not yet conclusively resolved. This project would advance the discussion to a new level. The introduction of national bridge inspection requirements represents an existing benchmark. The next one would be the introduction of bridge management standards. In the process, bridge inspection requirements will most likely be reviewed and enhanced.

COMMITTEE A3C07 – ROADSIDE MAINTENANCE

A3C07-01: Best Management Practices for Controlling Invasive Roadside Weeds

Problem: Roadsides are vulnerable to infestation by herbaceous and woody weeds due to a variety of circumstances: disturbing of the soil in initial construction and on-going maintenance; limited vegetation maintenance; shared right-of-way border with numerous properties, and varying land uses. Roadside conditions that invite invasion also support the spread of invasive weeds. Plants considered "invasive" are typically not contained by traditional vegetation management programs. Current practices of controlling invasive weeds require a roadside maintenance effort beyond that associated with regularly scheduled maintenance. Failure to control these plants increases driving hazards to motorists due to encroachment onto the shoulder and near foreslope area, increases snow and ice control maintenance by shading the roadway surface and increasing snow drifting, reduces sight distance around horizontal curves, and increases wind storm debris on the roadway from weak-wooded plant species. When these plant species migrate up and down the right-of-way, they pose an economic and ecological threat to adjacent properties.

Transportation agencies need a systems-based program to suppress and replace invasive plant communities, one from which specific agencies can develop a strategy of best maintenance practices suited to their local roadside environments.

Objective: Develop a systems approach to roadside maintenance to control invasive weeds to deal with a wide variety of invasive plant species which occur in a wide range of roadside environment conditions (wet land, rain forest, semi-arid prairie, high desert, etc.). Each maintenance practice included in the comprehensive strategies must be characterized by cost-effectiveness in reducing hazards to motorists, effectiveness in reducing negative ecological impacts within the right-of-way and to abutting property, and maintenance personnel impacts (training, safety, etc.). The organization of this approach and its application to controlling invasive roadside weeds must be able to be incorporated in a preventive maintenance philosophy to roadside maintenance and must permit the using agency to identify the best maintenance practice considering their specific roadside environment. Research from the fields of forestry and agronomy, and

vegetation maintenance practices from outside the United States and Canada, must be considered in developing this systems approach.

Key Words: Noxious weeds, integrated pest management, integrated vegetation management.

Related Work: Penn DOT has research under way at Penn State University seeking methods of rehabilitating roadsides infested with Canada thistle, tree-of-heaven, and Japanese knotweed. An NCHRP synthesis on the state-of-practice in U.S. maintenance addressing invasive weeds is anticipated. If this synthesis is available, the objectives and scope of this proposed project need to be adjusted to recognize the synthesis findings.

Urgency/Priority: As worldwide shipment of plants and personal travel continue to expand, it is imperative agencies have a wide range of strategies to deal with invasive plants to preclude having to periodically till the entire roadside and re-establish vegetative cover.

Cost: It is anticipated this project would require 3 years at a cost of $250,000.

User Community: AASHTO, FHWA, USDA, USDI.

Implementation: Each agency could adopt a "best maintenance practice" strategy for contract maintenance or for force-account maintenance suited to their unique roadside environment practices from the application of this systems approach.

Effectiveness: Public road user image of the highway agency should improve significantly due to a more "natural" roadside. Agricultural and environmental interests will be more sympathetic to highway maintenance. Improved consistency of roadway maintenance due to reduced impacts from invasive weeds should increase safety by a small margin and should increase quality of service to the road user significantly.

A3C07-02: Procedures to Reduce Tire Scrap Debris on Highways

Problem: Tire debris, especially from heavy trucks, is a hazard to small automobiles and motorcycles. The large rubber and steel belts that peel loose from large truck tires can damage a small automobile and can cause a driver to lose control of a small automobile at high speeds. In recreational regions and historic districts truck tire debris presents an aesthetic "eyesore" thought to have a negative impact on tourism efforts. It at least creates a negative effect in road user perception of quality of maintenance service.

Objectives:

1. Identify and document the reasons for heavy truck tire failures.
2. Identify possible improvements, and limits thereto, in truck tire re-treading processing that may reduce failure of the retread on the road.
3. Recommend standards for heavy truck tire recaps that may reduce on-road failures of the recapped tires.

4. Identify any highway maintenance procedures that can contribute to a lower rate of heavy truck tire failure.
5. Identify any heavy truck inspection procedures and enforcement procedure that can contribute to a lower rate of truck tire failure.
6. Identify best maintenance practices for heavy trucks that will contribute to a lower rate of failure in tires and communicate these practices to the trucking industry.

Key Words: Tire debris, recapped tires, tire failure, truck tire maintenance.

Related Work: An NCHRP synthesis addressing the state-of-practice in the manufacture and maintenance of recapped truck tires as it relates to heavy truck tire failure is anticipated. If this synthesis is available, the objectives and scope of this proposed project need to be modified to recognize the synthesis findings.

Urgency/Priority: The need to remove truck tire debris from the roadway is a priority. Debris on the roadway is a safety concern to the traveling public. As maintenance forces are downsized, less time is available to remove tire carcasses from the roadway. Tire debris distracts from the aesthetic qualities of highways and from areas promoting tourism and recreation.

Cost: It is anticipated that the proposed project will require 12 to 18 months to complete at a cost of $150,000.

User Community: AASHTO, ATA, NHTSA, OMCS, CVSA.

Implementation: Distribute recommended heavy truck tire maintenance practices intended to reduce tire debris to all organizations of the trucking industry. Recommend legislation to advance standards for manufacture of recapped truck tires and maintenance of regulated trucking to reduce tire failure. Recommend revisions to inspection procedures and regulation enforcement to reduce heavy truck tire failure.

Effectiveness: Reduced truck tire debris will increase highway safety, especially to small automobiles and motorcycles. Reduced truck tire debris will enhance public aesthetic appreciation of the roadside. Reduced truck tire debris will release maintenance resources for more attention to physical maintenance of the roadway. Reduced heavy truck tire failure will reduce the cost of truck transportation.

A3C07-03: Slope Stabilization with Native Grasses

Problem: Obtain stabilization of bare slope areas with native warm season grasses within a sufficient time frame to prevent soil erosion, siltation, water contamination and drainage way impediment. Also provide the aesthetic value and the natural habitat that is conducive to the wildlife community.

Objective: The research will identify those native warm season grasses that will establish quickly so as to prevent soil erosion and to provide the wildlife habitat and the aesthetic value that are desired.

Key Words: Warm season, wildlife habitat, soil erosion.

Related Work: Unknown.

Urgency/Priority: Relative urgency.

Cost: $15,000.

User Community: AASHTO, FHWA.

Implementation: The effective establishment and resulting effective control of soil erosion could give credence to the selective use of native grasses in the Department's seeding and protective specifications.

A3C07-04: Control of Storm Water Run-Off on Highway Construction Projects

Problem: The disturbance of the soil profile during excavation for the construction on new highway facilities leaves the soil in such a condition that when rainfall occurs the soil is susceptible to erosion. Soil that has not been properly compacted or stabilized will move from the site and create unsightly conditions, cause siltation in drainage structures, impede the flow of run-off in drainage ways, and cause the loss of topsoil from slope areas.

Objective: This research will result in the development of specific procedures and methods that will control the adverse effects of storm water run-off.

Key Words: Rainfall precipitation.

Related Work: Unknown.

Urgency/Priority: Relative urgency.

Cost: $10,000.

User Community: AASHTO, FHWA.

Implementation: These improved procedures and methods will be adopted and included in best management plans for highway road construction.

A3C07-05: Relationship of Vegetation Management to Roadkill

Problem: A number of state maintenance departments believe that the very thing we do in the name of safety, frequent mowing, draws grazing critters to the rights-of-way, and accidents increase. If this is true, maintenance should explore alternative vegetation management controls to lower roadkills and related property damage.

Objective: This study will determine if a correlation exists between frequent mowing and increased animal collisions. The benefit of such a study is to increase motoring safety. An additional benefit might be a proven reason to move to integrated vegetation management where mowing is only one of the tools in the toolbox of solutions.

Key Words: Integrated vegetation management, safety, roadkill, mowing.

Related Work: Being investigated by the states of Kansas and Utah. A northeast, southern, and northwest state could be added for regional differences.

Urgency/Priority: Some investigations in western states are implying this relationship. Lives and property damage can be saved, which is transportation's ultimate priority. Most importantly, deer populations in the U.S. have exploded, which suggests increased collisions if this problem is not explored immediately.

Cost: This project can be approached in a number of ways, depending on existing records within states. If record keeping of management techniques is not adequate, more time will be needed to make the comparisons. The research should be done in 3–5 states to reflect some regional differences in practices and kinds of wildlife. Total research cost should be approximately $150,000.

User Community: AASHTO, FHWA, all agencies and levels of maintenance.

Implementation: Conclusions of this study would have application for all land managers at federal, state, and county levels. All would be interested in saving human costs as well as wildlife costs through vegetation management.

Effectiveness: The results of this effort could be used by roadside managers to reduce the frequency of collisions between vehicles and wildlife.

COMMITTEE A3C08 – MAINTENANCE EQUIPMENT

A3C08-01: Development of Guidelines for Control of Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) in Vehicles

Problem: The recent expanding use of microprocessor-based electronics in modern automotive applications has led to problems of compatibility between various pieces of installed after market electronic equipment with original equipment manufacturer (OEM) systems. RFI between electronic systems has resulted in random failure of automotive systems, both OEM and after market components. Increasing instances herald a major problem. Failures of critical vehicular control and signaling systems due to EMI/RFI have affected the safety and operation of these vehicles.

It should be noted that state departments of transportation (DOTs) depend heavily on the reliable use of two-way radios, as they are used extensively in today's operations. Research proposed would benefit DOTs operations throughout the United States.

Although extensive EMI/RFI testing by the OEM apparently provides sufficient protection for OEM installed electronics, there is evidence of after market equipment compatibility problems (including two-way mobile radios, cellular phones, after market alternative fuel conversion systems, and personal computers) that merit both radiated and susceptibility EMI/RFI tests for such add-on equipment. Shielding appears to be grossly insufficient with regard to any electronics other than those installed by the OEM.

Objective: A requirement exists for the development of guidelines for RFI limits in motor vehicles. Recommended wording for inclusion in procurement specifications for vehicles and ancillary equipment must be developed. Additionally, instruction for proper installation of after market equipment must also be developed to ensure designed safeguards are not defeated.

Sample vehicles, including light (at least) trucks, from the major OEMs should be tested for EMI/RFI compatibility using representative samples of after market add-on equipment. Limits established by the OEMs should be used as test standards, initially. New limits should be established as tests determine weaknesses and vulnerabilities.

Suggested EMI/RFI test formats to follow include military standards for EMI/RFI testing Mil-Stds 461/462. Some states such as Texas have already invested both time and equipment in order to develop in-house testing capabilities related to EMI/RFI problems. These efforts should be considered as a basis for developing a more comprehensive program that would be beneficial on a nationwide scale. Texas DOT suggests as a test outline the following:

TASK 1 - TEST SETUP: Prepare test procedures and test facilities; determine and acquire equipment to be tested; and prepare test plan.

TASK 2 – TESTS: Conduct tests; and analyze test results.

TASK 3 - REPORTING AND DELIVERABLES: Prepare test results and forward to the major OEMs for possible incorporation into future vehicle designs, to state DOTs for incorporation their procurement specifications, and to AASHTO for consideration as a standard; and prepare guidelines for after market equipment suppliers defining specific levels of EMI/RFI isolation to be met.

Key Words: Radio frequency interference, electromagnetic interference, radiation shielding, electronic hardening, spurious signal isolation, inductive or electromagnetic coupling.

Related Work: Extensive EMI/RFI research, and system applications of same, exist in Department of Defense (DOD) system development efforts. Texas DOT has funded significant investigation in this area and their efforts would also provide a useful baseline for proposed research.

Cost: Test setup – 2-months - $10,000; material cost (assumes vehicles loaned if required) - $20,000; tests – 8-months - $80,000; reporting and deliverables – 2-months - $10,000; duration/total cost – 12-months - $120,000; total cost $240,000.

Urgency/Priority: Growing concerns of RFI failures involving antilock brake systems and engine real-time management systems have been validated. Possible interference with air-bag deployment control systems is a concern. Recommended RFI sources that should be investigated include high power two-way mobile radios (multiple frequencies to be tested) and after market alternative fuel conversion kits utilizing microprocessor controllers. Ancillary systems added subsequent to vehicle delivery such as distribution rate controls, timing circuits for roadway paint application, pavement temperature monitoring devices, etc., have the potential to interfere with adjacent electronic systems. It is recommended that this evaluation be performed as soon as possible due to the growing awareness that safety is a real concern and issue in this problem area.

User Community: The user community for this research includes the transportation infrastructure construction and maintenance representative organizations, utilities (installation and maintenance) representative organizations, and organizations representing OEMs for vehicles and after market ancillary equipment products associated with the foregoing communities.

Implementation: The proposed research might be implemented through providing as deliverables recommended additional equipment specifications to user community associations for further dissemination through journals, and results of research provided for information to vehicle and after–market OEM associations for like promulgation, as well as to AASHTO for consideration as standards for infrastructure–associated equipment utilization.

Effectiveness: The social impacts of implementation of technically sound recommendations will be real but difficult to evaluate. EMI/RFI effects are often not associated with their causal factors among operators. Effectiveness will be inferred from follow-up with organizations implementing research recommendations that report fewer EMI/RFI events.

A3C08-02: Standardization of Warning Lights for Highway Maintenance and Service Equipment

Problem: Highway maintenance and service equipment has traditionally used amber warning lights (beacons) to alert approaching motorists of potentially hazardous situations. More lights have been added to vehicles in an attempt to help the traveling public see the equipment and avoid it. Some state agencies and private contractors are using combinations of amber and white strobe lights for more effective visibility. Blue warning lights have come into use in addition to amber in the belief that visibility is improved.

Maintenance and service personnel are now using new types of warning lights initially seen only on emergency response equipment and police vehicles: strobes, light bars, lighted “arrow sticks,” and alternating (wig-wag) flashing. A concern exists that the progression of lighting on highway equipment will dilute motorist awareness of emergency vehicles as they respond to calls.

There appear to be no uniform standards or specifications for lighting currently approved by AASHTO. There is no conclusive guidance on the best lighting combination

that should be installed for maximum effectiveness, and some of these devices, such as white strobes, may temporarily blind drivers, creating driving hazards.

Objective: Investigate the most effective lighting arrangements, types, colors, locations, and flashing sequences to provide the quickest and most effective motorist response to avoid highway maintenance equipment. The study should be organized to make use of existing studies, including studies on the visibility, physiological and psychological aspects of motorists reacting to situations.

The aspects of a motorist detecting a situation, recognizing it, making a decision, and reacting must all be included. It also is important to consider physical limitations such as color blindness and effectiveness of lights in daylight, under different types of street lighting, and under other background conditions. Studies conducted by NCHRP, FHWA, lighting companies, state DOTs (such as New York, South Dakota, and Minnesota), and the National Institute for Standards and Technology have provided a great deal of information in these areas.

From this review, the factors necessary for selecting the most effective lights or light combinations can be selected for consideration. Various situations for field tests must be identified, and the most promising alternatives selected. Some laboratory studies may be needed to supplement the existing studies. Field tests must be conducted to evaluate the alternatives under varied conditions and situations. Recommendations can then be prepared for what lighting is most effective in various situations, and what practices should be eliminated. The final deliverable is a standard or specification for consideration by AASHTO.

Task 1 - REVIEW LITERATURE: determine alternatives available; determine factors to be considered; and determine areas for laboratory study for supplemental data.

Task 2 - CONDUCT LABORATORY TEST: analyze data and evaluate alternatives to determine which are acceptable; identify practices that should be avoided; determine advantages/ disadvantages of alternatives; and provide test plan for field tests.

Task 3 - FIELD TEST PROMISING ALTERNATIVES: analyze test data; and form conclusions.

Task 4 - RECOMMEND MOST EFFECTIVE PRACTICES AND IDENTIFY UNACCEPTABLE PRACTICES.

Task 5 - PREPARE DRAFT FOR AASHTO TO CONSIDER PROMULGATING AS A STANDARD.

Urgency: There is a high probability that this research will reduce the costs to society of preventable accidents by the traveling public and reduce the cost to taxpayers by cutting down on maintenance equipment damage and crew injuries. Adoption of the findings by AASHTO in the form of standards will ensure timeliness and consistency in the use of highway maintenance and service vehicles warning light schemes. This decision will reduce the confusion to the traveling public in the recognition and response to these warning light devices.

Cost: Review literature – 2-months - $10,000; conduct laboratory test – 12-months - $80,000; field test – 6-months - $40,000; recommend most effective practices – 2-months - $10,000; prepare draft for AASHTO – 2-months - $10,000; total cost – 24-months - $150,000.

User Community: The user community would include state, county, and municipality government fleets.

Implementation: Various situations for field test must be identified, and the most promising alternatives selected. Some laboratory studies may be needed to supplement the existing studies. Field tests must be conducted to evaluate the alternatives under varied conditions and situations.

Effectiveness: Recommendations can then be prepared for what lighting is most effective in various situations, and what practices should be eliminated. The final deliverable is a standard or specification for consideration by AASHTO.

A3C08-03: Standardized Equipment Classifications

Problem: Manufacturers produce construction equipment in a variety of configurations and class sizes. Since there is no standardized equipment classification system, it is very difficult to develop competitive comparisons of the equipment produced by several manufacturers.

Objective: Develop a standard classification system with recommended weights, hp, capacity, and other specifications, i.e., tractor-loader-backhoe in classes with recommended weights, hp, loader capacity, backhoe size. This would encourage manufacturers to build similar size units with comparable specifications.

Key Words: Classification system, size, capacity, classes.

Related Work: Although many fleet operators develop their own internal equipment comparisons, most of the effort has come from the private industry. Such comparisons tend to be slanted towards the vendor's own equipment.

Duration/Cost: 12 months - $85,000.

User Community: The user community would include state, county, and municipality government fleets.

Implementation: Development of a standard classification system with recommended weights, hp, capacity, and other specifications, i.e., tractor-loader-backhoe in classes with recommended weights, hp, loader capacity, and backhoe size, would encourage manufacturers to build similar size units with comparable specifications.

Effectiveness: The ability to easily compare "like" equipment from various manufacturers would encourage manufacturers to build similar size units with

comparable specifications, resulting in more competition, lower prices, and a larger selection of available equipment.

A3C08-04: Preventive Maintenance Program for Fleet Equipment

Problem: The identification and correction of minor equipment problems are considered to be the cornerstone of an effective preventive maintenance program. If minor problems are not corrected in a timely manner, serious problems will develop. The costs, in terms of equipment down time and actual repairs, to correct serious equipment problems are often significantly higher than the cost of correcting the minor problem.

Objective: Identify the benefits and cost of using mechanics for a preventive maintenance program. Develop a model preventive maintenance program for highway departments to implement.

Key Words: Preventive maintenance; minor equipment; repairs.

Current Activities: Each individual agency develops unique PM programs, none of which may be considered standard.

Urgency: Preventive maintenance programs for highway fleet equipment could be quite cost-effective.

Duration/Cost: 12 months - $85,000.

User Community: The user community would include state, county, and municipality government fleets.

Implementation: Development of a standardized means (methodology) for identifying and correcting minor equipment problems (before they become major) will enhance an overall preventive maintenance program.

Effectiveness: The costs, in terms of equipment down time and actual repairs, to correct serious equipment problems are often significantly lowered if the problems are detected and corrected during a regularly scheduled preventive maintenance program.

A3C08-05: Equipment Management Training

Problem: There have been national FHWA sponsored courses taught in the past for equipment managers. There are also equipment management courses for small and medium public works agencies. There are, however, no equipment management courses available for professional equipment managers from large counties, cities, or state departments of transportation.

Objective: Create a multi-day, or perhaps multi-week, course for professional equipment managers. It should cover such advanced topics as inventory theory, engineering

economic analysis of equipment, the development of equipment management plans, economic analysis of component rebuild intervals, reliability analysis, employee management and motivation, employment training, etc.

Key Words: Inventory theory, reliability analysis, equipment management courses.

Related Work: There have been national FHWA sponsored courses taught in the past for equipment managers. There are also equipment management courses for small and medium public works agencies.

Urgency: Knowledgeable professionals are required to protect the significant investment by transportation agencies in equipment fleets.

Duration/Cost: 12 months - $75,000.

User Community: The user community would include state, county, and municipality government fleets.

Implementation: Development of equipment management training courses, to be made available to professional equipment managers from large counties, cities, and state departments of transportation.

Effectiveness: Training courses will be structured so that objective grading can be assessed at the end of the course. Pass/fail criteria will be developed.

A3C08-06: Avoiding Buried Infrastructure

Problem: There exists a need for an industrial-augmented reality system used to assist service and maintenance personnel working on complex underground substructures (trenching services) utilizing overlaying blueprint information with integrated GPS (global positioning satellite) spatial information and physical sensing and displaying the combined information on an operator's heads-up display in the equipment cabin. Preventing accidents and aiding the trenching operation will save time and possible accidents. Warning display information should be developed which will identify hidden or buried hazards before trenching operations begin.

Objective: Create an information system that will utilize low-cost technological advances and new wireless infrastructures in order to associate physical space with relevant (warning) information. Develop a set of requirements; develop and assemble requisite hardware, software, and Internet-provider networks. Perform field trials.

Key Words: Global positioning; GPS; wireless communication; digital information.

Urgency/Priority: Due to the complexity and leading edge technologies assumed to be used in this research, a high priority should be assigned. A four-year research program is estimated and initiation should begin as soon as possible.

Cost: Four-year research and development program: first year - research and requirements development - $150,000; second year - prototype development, field test - $150,000; third/fourth year – full-scale 2-year feasibility test - $150,000; for a total of $450,000.

User Community: Once developed, such a concept would be used by state, federal, private and commercial industry. Anyone engaged in trenching activities would benefit from such technology.

Implementation: Implementation will be based on developing user-friendly hardware and software platforms easily obtainable from the commercial market (COTS—commercial off the shelf).

Effectiveness: Effectiveness will be based on investment cost (ROI) versus the ability to quickly gather, assimilate, distribute, and utilize warning information.

A3C08-07: Putting Information in Places

Problem: As global positioning (GPS—global positioning satellites), Internet service, wireless communication (cellular telephone; alpha-numeric pager; v-mail (voice e-mail); two-way mobile radio), and mobile display technologies continue to advance, our notion of place will change. A need will develop that can associate *information with places*.

Objective: Create an information network that will utilize low-cost technological advances and new wireless infrastructures in order to associate physical space with relevant information. Develop a set of requirements; develop and assemble requisite hardware, software, and Internet-provider networks. Perform field trials.

Key Words: Global positioning; GPS; wireless communication; cellular; Internet; voice e-mail; v-mail; digital information.

Urgency/Priority: Due to the complexity and leading edge technologies assumed to be used in this research, a high priority should be assigned. A 4-year research program is estimated and initiation should begin as soon as possible.

Cost: Four-year research and development program: first year - research and requirements development - $250,000; second year - prototype development, field test - $250,000; third/ fourth year – full-scale 2-year feasibility test - $250,000; for a total of $750,000.

User Community: Once developed, such a concept would be used by everyone; the ideas are boundless, as are the users.

Implementation: Implementation will be based on developing user-friendly hardware and software platforms easily obtainable from the commercial market (COTS—commercial off the shelf) in conjunction with Internet service providers (ISPs).

Effectiveness: Effectiveness will be based on investment cost (ROI) versus the ability to quickly gather, assimilate, distribute, and utilize *information with places*.

A3C08-08: Outsourcing Equipment Fleet Operations

Problem: There is significant interest in outsourcing equipment fleet support and management. A review of anecdotal evidence discloses stories of successes and failures in practice. Outsourcing varies in degree from those that take advantage of commercial specialization to affect economies, e.g., outsourcing frame straightening, radiator repair, wreck repair, painting, etc., and those that have had their entire fleet management operation contracted out. Guidance is not available to aim the fleet manager toward the optimum mix of in-house and outsourcing for fleet management or support services.

Objective: The objective of this research effort would be to fund a synthesis to document objective experience in outsourcing over a representative period (5 to 10 years) from all state department of transportation (DOT) fleets.

Key Words: Outsourcing, make/buy decisions, turnkey fleet management, commercialization, service contracts, purchased services, National Accounts service providers, etc.

Related Work: NCHRP Synthesis 246, Outsourcing of State Highway Facilities and Services, would be a complementary study; however it did not address equipment maintenance or management operations. TRB Committee A3C08 proposed a study in 1998, "Outsourcing of State Department of Transportation Equipment and Equipment Maintenance Facilities and Services," and in 1990, A3C08 proposed research on the subject, "Contract vs. In House Equipment Maintenance."

Urgency/Priority: Commercialization of equipment maintenance services and facilities is popular as a hedge against growth in government. Such programs have had mixed results. When they prove to be ineffective, recovery costs are high. It is urgent that states review alternatives and develop strategies that result in both economic and effective operations.

Cost: Required literature searches, numerous state fleet manager interviews, with associated travel, and resulting collected, analyzed data, would require about 2½ man-years of engineering analyst labor and ½ man-year of administrative support. Such a study is estimated to require a budget of $250,000 and 1 year to complete.

User Community: The user community would include state, county, and municipality government fleets.

Implementation: Implementation would be accomplished by promulgation of resulting documentation as an educational tool in support of preparing optimum outsourcing strategies.

Effectiveness: There are appropriate outsourcing goals. No organization is efficient in all tasks. Optimizing the mix of in-house and outsourcing of functions will result in a more economic program. Proposed synthesis would improve the chances for government fleets to approach the optimum position.

A3C08-09: Equipment Trailer Decking Material Recycled Alternatives

Problem: Equipment trailers (i.e., heavy-duty, dual-wheel, tandem-axle, fixed-deck trailers with sloped-rear or bi-fold loading ramps, capable of carrying loads of 20,000 to 30,000 pounds) are used to transport various types of highway maintenance and construction equipment. These trailers are traditionally built using decking materials made from 2-inch-thick oak or apitong hardwoods. The overall trailer design is driven by the load-bearing strength of the decking material used, directly affecting the number of frame cross-members required in order to support the types of loads transported, ultimately the load carrying capacity.

In order to be "environmentally sensitive" (apitong is becoming rare and in limited supply worldwide) the use of recycled decking products made from various substances has been tried, with mixed results. The load-bearing strength of recycled decking products has been demonstrated to be less than that of their hardwood counterparts. The trailer must be designed with a more robust frame, requiring a greater number of cross-members in order to support the weaker recycled decking product. This results in a greater overall trailer weight and thus a reduced payload capacity.

Objective: Establish engineering design criteria for recycled decking material used in trailer applications. Design limits will be established based on the loads typically carried by these type(s) of trailers. Life cycle performance criteria will be established.

Key Words: Equipment trailer; decking; recycled; rumbar; oak; apitong; load bearing.

Related Work: The commercial trailer industry has offered recycled decking products as an option for several years, normally claiming exceptional performance and value.

Urgency: The emphasis on using recycled products wherever possible should be a catalyst for this research.

Cost: Research and development – 12-months - $180,000; 1-year performance test – 12-months - $5,000; for a total of $185,000.

User Community: The user community would include state, county, and municipality government fleets, along with private and commercial entities.

Implementation: Perform a review of current industry-offered recycled decking products. Establish engineering design criteria for recycled decking material. Establish design limits. Life cycle performance criteria will be established. Cost-effectiveness based on all engineering and cost variables will be considered. Perform a 1-year, real-world test to demonstrate performance of various candidate products.

Effectiveness: Identify recycled decking products that are cost-effective and will perform with the same engineering specifications as hardwoods. The use of recycled products that result in a lower life cycle cost and less dependency on natural resources would benefit everyone.

A3C08-10: Synergistic Spatial Data Capture System for Maintenance and Construction Equipment

Problem: Much of today's modern highway maintenance and construction equipment is designed using sophisticated electronic control (application) systems managed by complex computers. A tremendous amount of data is produced and made available for capture and subsequent re-use either for detailed record keeping functions or data analysis. As global positioning satellite (GPS) technology, real-time Internet service, wireless communication (cellular telephone; two-way mobile radio) and mobile display technologies continue to advance, our capability (and capacity) to record large amounts of data correlated with spatial location information (time and space) has become technologically practicable and feasible. There exists a need to capture such spatial data *synergistically*, in real time, for immediate use or logged on-board the vehicle for later downloading to other systems used for evaluation. Such a system could be defined as a Synergistic Spatial Data Capture System (SSDCS).

Objective: Create an electronic network, SSDCS, utilizing low-cost technological advances and new wireless infrastructures in order to capture/record specific data and corresponding spatial position information existing in modern highway maintenance and construction equipment. Develop a set of requirements; develop and assemble requisite hardware, software, GPS, and electronic networks. Perform field trials. Show proof-of-concept.

Key Words: Global positioning; GPS; wireless communication; cellular; Internet; digital information; data-logging.

Urgency/Priority: There currently exists a need to develop this network for use in complex equipment primarily controlled by sophisticated computer systems.

Cost: Two-year research and development program: first year - research and requirements development - $250,000; second year - prototype development, field test - $250,000; for a total of $500,000.

User Community: Once developed, such a concept would be used by state, federal, commercial and private enterprise.

Implementation: Implementation will be based on developing user-friendly hardware and software platforms easily obtainable from the commercial market (COTs—commercial off the shelf).

Effectiveness: Effectiveness will be based on investment cost (ROI) versus the ability to quickly gather, assimilate, distribute, and utilize spatially referenced on-board data.

COMMITTEE A3C09 – WINTER MAINTENANCE

A3C09-01/A3C01-03: Evaluation of Sensors and Related Systems for Winter Maintenance

Problem: Significant experimentation has been undertaken in recent years to evaluate technology to sense roadway conditions through roadway weather information systems (RWIS) and through "concept maintenance vehicles" to sense the application of snow and ice control treatments while simultaneously dynamically sensing the road surface to tire interface conditions. What is lacking is an integrated analysis of the accuracy of these various sensing systems to be able to calibrate the snow and ice control measures taken to the effectiveness of the results. For instance, it is suspected that the RWIS road sensor instrumentation may not retain proper calibration to actual roadway surface conditions as various anti-icing and deicing chemicals are applied to the roadway surface. Likewise, the calibration of the sensors dynamically controlling the rate of application of various chemicals in pre-wetting processes and anti-icing processes needs to be related to an accurate measurement of the existing roadway conditions before application, immediately after application, and of short-term predicted road surface conditions after application. Finally, these various data need to be integrated and presented in a way that the analysis can produce real-time decisions or adjustments to snow and ice control treatments.

Objectives: The various objectives of this proposed project include:

1. Assess and evaluate the extent of any lack of accuracy between RWIS instrumentation estimates of roadway surface conditions and actual conditions. Develop a corrective solution, as may be needed, so that RWIS instrumentation provides an accurate report of actual field roadway surface conditions.
2. Assess and evaluate the extent of any lack of accuracy between on-board maintenance vehicle sensors dynamically measuring the application of snow and ice control treatments and dynamically measuring roadway surface conditions. Develop a corrective solution, as may be needed, so that the on-board vehicle sensor dynamic measurements provide an accurate report of actual treatment and surface conditions.
3. Correlate the resultant accuracy-corrected RWIS report of actual field roadway surface conditions to the corrected on-vehicle dynamic measurement of roadway surface conditions.
4. Develop a real-time decision process for application of snow and ice control treatments based on integrated data streams from RWIS and on-vehicle sensors.
5. If new sensing devices are required to achieve real-time integration of RWIS and on-vehicle data integration, prepare a system design for such sensors to achieve real-time integration.

Key Words: RWIS, road sensors, on-vehicle sensors, anti-icing, deicing, integrated decision data.

Related Work: Concept maintenance vehicle testing in Minnesota, Iowa, and Michigan.

Urgency/Priority: This proposed project is deemed necessary to bring user expectations of winter maintenance level of service to engineering management control of the application of snow and ice control.

Duration/Cost: It is anticipated this proposed research would require 3 years and approximately $350,000.

Implementation: Shared data and correlations among states and local agencies having RWIS installations will lead to increased accuracy and better winter maintenance planning and management. Cooperative state implementation and evaluation projects on correlation of on-board sensor data with RWIS data will lead to equipment production being regularly available through commercial sources.

Effectiveness: Improved accuracy of data, improved reliability of measurements related to maintenance levels of service, and integration of roadway surface data with snow and ice control treatment application data will lead to reduced chemical application. This will reduce winter maintenance costs and increase environmental quality.

A3C09-02: Applying Total Quality Management to Winter Highway Maintenance

Problem: Winter highway maintenance (WHM) is provided by state and local agencies as a service to the road using community. To an extent, WHM can thus be considered a service industry. It would seem appropriate, therefore, to apply total quality management (TQM) or other similar quality programs to WHM.

Objective: This project will define what is needed to apply TQM to WHM. It will develop two model programs (one for a state agency, one for a local agency) and will work with at least two agencies to implement these programs. The project will monitor, for a period of 2 years, the success of these programs. On the basis of the monitoring, changes in the programs will be proposed. After this, the programs will be made available to other agencies as the final product of the project.

Key Words: Winter highway maintenance, quality programs, maintenance management.

Related Work: No related work in this area is known to be ongoing in the United States. However, quality of service is a major factor in winter maintenance activities in Europe.

Urgency/Priority: Winter maintenance activities are provided as a service to road users, but few if any efforts have been made to measure how well that service is provided, *in ways that relate directly to end user expectations*. This lack needs to be addressed with some urgency.

Cost: Expected cost is $125,000.

User Community: The results of this project would be applicable in all areas of the country that experience winter weather. Thus AASHTO, NACE, and APWA would all have an interest, as would FHWA.

Implementation: The most promising model for implementation of results would be that used in the AASHTO Lead States program, whereby a number of agencies act as "champions" for the new methodology.

Effectiveness: This project could create significant improvements in the quality of winter maintenance activities. To measure these benefits, it would be best to use standard quality measurement tools.

A3C09-03: Reliability and Uncertainty: Their Role in Winter Highway Maintenance

Problem: Good decisions in winter highway maintenance (WHM) rely on a variety of inputs. Each such input is subject to uncertainty and under certain circumstances these uncertainties may combine to create a set of inputs that drive inappropriate outputs. In addition, failure of any of these inputs may degrade the ability to make timely and pertinent decisions. There is a need to determine how uncertainty affects decisions within WHM. On the basis of this determination, limits of accuracy for a range of sensors can be established and used in specifications. Likewise, by identifying critical sensors and specifying needed levels of reliability, the level of redundancy of various system components can be developed.

Objective: This project will examine current system components with respect to both reliability and uncertainty. On the basis of the findings made for the sensors, the effects of these factors will be calculated through to final decisions to determine acceptable levels of reliability and uncertainty.

Key Words: Winter highway maintenance, reliability, uncertainty, decision-making tools.

Related Work: No related work in this area is known to be ongoing in the field of winter maintenance.

Urgency/Priority: As more sophisticated tools and sensors are being used in winter maintenance to make critical decisions that can dramatically affect road clearing activities, it is vitally important to know how reliable the information is that decisions are being based on. At present, any such knowledge of reliability is purely ad hoc, in so far as it is based on limited experience. As the user community grows, a more meaningful approach to reliability and uncertainty management in winter maintenance is required.

Cost: Expected cost is $250,000.

User Community: The results of this project would be applicable in all areas of the country that experience winter weather. Thus AASHTO, NACE, and APWA would all have an interest, as would FHWA. The results also could be expanded to the whole ITS arena, in so far as ITS relies on sensor information that may be faulty.

Implementation: The most promising model for implementation of results would be that used in the AASHTO Lead States program, whereby a number of agencies act as "champions" for the new methodology.

Effectiveness: Wrong decisions in winter maintenance can have serious effects, in the worst cases threatening lives, property, and safety at a fundamental level. The results of implementing the project described here would be to substantially improve the appropriateness of winter maintenance actions taken on the basis of sensor input.

A3C09-04: Developing a Systems Approach to Winter Highway Maintenance

Problem: When an agency fights a winter storm effectively, it is the result of a number of groups within that agency working together effectively. In short, effective winter highway maintenance (WHM) requires that a system should work. Yet (with few exceptions) WHM has not been treated with the tools of systems engineering and management.

Objective: This project will apply the tools of systems engineering and management to the WHM activities of at least one state and one local agency. The application of these tools will lead to a series of recommendations for changes in approach and methodology.

Key Words: Winter highway maintenance, systems engineering.

Related Work: No related work in this area is known to be ongoing in the field of winter maintenance.

Urgency/Priority: Many complex entities have to combine together in order to fight a winter storm successfully. Systems engineering provides a framework in which this can be done. At present, the coordination of these disparate entities is managed on an ad hoc basis, and thus sometimes the coordination is less than optimal. The need for improvement in this regard is clear.

Cost: Expected cost is $125,000.

User Community: The results of this project would be applicable in all areas of the country that experience winter weather. Thus AASHTO, NACE, and APWA would all have an interest, as would FHWA.

Implementation: The most promising model for implementation of results would be that used in the AASHTO Lead States program, whereby a number of agencies act as "champions" for the new methodology.

Effectiveness: This project could create significant improvements in methodology used to fight winter storms. Measuring effectiveness would require comparison of overhead costs associated with winter maintenance activities both with and without a systems engineering approach.

COMMITTEE A3C12 – SIGNING AND MARKING MATERIALS

A3C12-01: Pavement Marking Retroreflectivity for 30-Meter Geometry

Problem: There are currently no national standards that are available to calibrate either hand-held or mobile instruments of 30-meter geometry. As more agencies go to performance standards, use of 30-meter instruments will increase to measure retroreflectivity performance. All these instruments have calibration standards that have not shown consistent correlation. Recent ASTM "light tunnel" readings have shown variation as large as 10 percent among organizations and instruments. There is a need for calibration standards that can be used to resolve discrepancies that now exist among the calibration of different instruments.

A related problem is that there is no accepted minimum standard of retroreflectivity with respect to driver need for reflectivity in the driving task. Previous research by Henry at PTI, Graham at UNC-Charlotte, and Attaway at ITRE has suggested minimum required reflectivity for drivers based on visual observer response and using 15-meter hand-held reflectivity instruments. No simple or direct correlation has been found between 15-meter retroreflectivity instruments and 30-meter instruments. There is a need for minimum standard retroreflectivity values related to driver expectations and driver needs.

Objectives: The proposed research project objectives include the following:

1. Manufacture of standard reference material samples for calibrating 30-meter instruments.
2. Specification of an NIST standard calibration of 30-meter instruments and measurement of the retroreflectivity of the standard reference material samples. Calibration must be applicable to all 30-meter instruments.
3. Develop guidelines for suggested minimum values of retroreflectivity for a wide variety of materials used for pavement markings based on the visibility needs of a cross-section of drivers of different ages.

Key Words: Retroreflectivity, pavement markings.

Related Work: FHWA is currently evaluating data submitted by GME of mobile measurements of existing materials in place on the roadway. MinnDOT is developing a project to compare observer visual evaluations to retroreflectivity as measured by a mobile 30-meter instrument. FHWA currently has a project at HITEC to evaluate the performance of existing retroreflectometers but this project will only evaluate each instrument with respect to the manufacturer's criteria (no comparison of one manufacturer's instrument to another). NIST has had some discussions regarding the need to develop Standard Reference Materials for calibration of 30-meter instruments.

Urgency/Priority: There is much pressure for agencies to apply 30-meter geometry retroreflectivity to the evaluation of pavement markings. Without standard calibration among the various instruments available and with respect to driver visual needs, it will be very difficult to achieve uniformity with the traffic control environment.

Duration/Cost: It is anticipated that this proposed project will require 24 months at a cost of $400,000.

User Community: FHWA, AASHTO.

Implementation: Samples of the Standard Reference Materials will be made available, along with the calibration specification, for calibrating 30-meter retroreflectometers. The guidelines for suggested minimum values of retroreflectivity for driver needs will be made available through the normal research information distribution channels.

Effectiveness: Having a common calibration method and a guideline for acceptable values of retroreflectivity will enable highway agencies to provide a uniform traffic control environment in pavement markings.

A3C12-02: The Aging Eye and Implications on the Visual Task of Driving

Problem: Recommendations and standards for lighting have been based on data that do not incorporate the natural degeneration of the visual capability with age. This is true for lighting at the workplace indoors as well as for standards set up for roadway lighting and proposed standards for retroreflective traffic control devices. The recommended luminance levels at the workplace and on the road, the restrictions of disability and discomfort glare, the intensities of traffic lights, and the studies on the legibility of traffic signs have been largely based on the eye of an age group of 20–30 years. Calculations reveal that a 70-year-old person needs about four times more light to achieve the same visual acuity as a 25-year-old. This has consequences for the design and recommendations for lighting as well as the soon to be proposed minimum standards/guidelines for signing and marking materials.

Objective: Quantify the various effects of age on vision and evaluate the lighting conditions and retroreflectivity of signing and marking materials that are necessary for the older driver to safely perform the tasks associated with night driving.

Related Work: Some work has been done by J. Graham at UNC-Charlotte to define the needs of the older driver.

Urgency/Priority: Every year the average age of the population is increasing due to the aging of the baby-boom generation. In 1993, FHWA was directed by Congress to establish minimum standards of retroreflectivity for signing and marking materials. Efforts to achieve this goal are finally coming to fruition and there are plans to publish the requirements in the new *Manual on Uniform Traffic Control Devices*. If guidelines are to be established, they should take into account the needs of our ever-increasing older generation.

Cost: $500,000.

User Community: The results of this work would be useful to FHWA, AASHTO, NHTSA, NACE.

Implementation: Results of the study would assist in the implementation of the guidelines for minimum retroreflectivity for signing and marking materials**.**

Effectiveness: Establishing minimum guidelines for retroreflective traffic control devices should improve the safety of driving at night. Night driving accounts for two-thirds of all related traffic fatalities. The immediate impact will be lives saved and fewer accidents at night.

A3C12-03: Determine the Efficacy of Changing from Lead Chromate Pigmentation to Heavy Metal Free Pigments in Hot-Melt Thermoplastic Traffic Markings

Problem: Is the health and/or environmental risk real for users of thermoplastic traffic markings?

Objectives: Silica encapsulated lead chromate pigments produce very efficient, cost-effective markings. However, lead and chromium are hazardous substances. Organic, lead-free pigments are an expensive, inefficient alternative. Suitable organic pigments are 12 times more expensive than an encapsulated lead chromate. If the lead-free issue is political rather than technical, then we are wasting money and requiring an inferior product for no real purpose.

Urgency: This subject is too sensitive for a private or state sponsored project. The separate states are changing to lead-free without any supporting data. Most states will be lead-free in 5 to 7 years and our most cost efficient marking system will no longer be as useful.

Cost: $250,000.

Duration: 1 year

A3C12-04: Pavement Markings for Cold-Weather Application

Problem: Asphalt pavement overlays are often completed late in the construction season. This makes it difficult to schedule and complete the installation of pavement markings on the new overlay. However, for good communication with drivers, adequate pavement markings that meet the requirements of the *Manual on Uniform Traffic Control Devices* are needed to provide traffic control during the winter months. Durable pavement marking materials are especially difficult to install during late construction season conditions because many of these materials are especially sensitive to cold temperature and high moisture conditions. If adverse installation conditions result in premature failure, the higher initial cost of durable marking materials results in much greater economic loss than if traffic paints are used. On the other hand, traffic paints are less durable and traffic paint service life is shorter on new pavements than on old pavements. Thus, using standard traffic paints to install markings on new pavements late in the construction season, especially in high traffic volume routes, reduces the effective life of the marking.

Objectives:

1. Develop new pavement marking materials designed to be installed under low temperature and high moisture conditions.
2. Evaluate the effectiveness of candidate marking materials in actual new pavement installations.
3. Conduct a cost-effectiveness analysis of each new candidate marking material tested.

Key Words: Pavement markings, cold-weather construction.

Related Work: An NCHRP synthesis on the state-of-practice in applying pavement markings in cold weather environments is anticipated. Any findings available from this anticipated synthesis should be considered in defining the final scope and objectives of this proposed project.

Urgency/Priority: The anticipated safety improvement and reduced life-cycle pavement maintenance cost resulting from successfully completing this project suggests it have a high priority.

Duration/Cost: The development and evaluation process is expected to require 30 months at a cost of $350,000.

User Community: AASHTO, FHWA, NACE, APWA.

Implementation: Disseminate the cost-effectiveness analysis results on marking materials found to be successful to all state DOTs, to NACE, to APWA for consideration by maintenance and traffic operations engineers and managers.

Effectiveness: Successful completion of this proposed research may permit some highway agencies to conduct tests/studies/analyses of asphalt pavement overlays for a few weeks longer than is now feasible without winter safety concerns, and to reduce the life-cycle cost of pavement markings on new pavements.

COMMITTEE A3C13 – SEALANTS AND FILLERS FOR JOINTS AND CRACKS

A3C13-01: Influence of Sealing Transverse Contraction Joints on the Overall Performance of Concrete Pavements

Problem: State-sponsored studies by Wisconsin DOT have concluded that sealed transverse contraction joints are not cost-effective in influencing overall pavement performance on doweled, short-jointed pavements. As a result, Wisconsin DOT no longer requires joint sealing for new concrete pavements. This practice is challenging traditional thinking. Other studies, such as the FHWA Performance of Concrete Pavements studies in 1990 and 1995, NCHRP 1-19 (1984), and the 1972 study sponsored by the HRB Committee on Sealants and Fillers for Joints and Cracks entitled “Effects of Various Sealing Systems on Portland Cement Concrete Joints,” have concluded that for

the pavements evaluated, sealing the transverse joints did provide an increase in pavement performance. The question of whether to seal joints in concrete pavements has been asked for more than 50 years. Conclusions were drawn in the 1970s based on the pavement types in service at that time, and those recommendations were used in the construction and maintenance of the Interstate Highway System in the United States. However, with the advent of drainable base materials, load-transfer devices, shorter joint spacing, and the identification of aggregates that are less moisture sensitive, the question has been raised again.

Currently, 98 percent of state highway agencies require transverse contraction joint sealing, adding about 2 to 7 percent to the initial construction cost and even more when considering resealing activities in life-cycle cost analysis. If the use of narrow, unsealed joints on short-jointed PCC pavements can provide similar long-term pavement performance with sealed joints under certain conditions, states can save millions of dollars in construction and maintenance costs by eliminating joint sealing on those projects. The reduction in traffic delays during resealing maintenance and increased worker safety also are possible benefits of the identification of pavements where not sealing the joints would be cost-effective.

Recent research in Wisconsin indicates the possibility that elimination of joint seals can be cost-effective on some projects. However, if the decision is made by highway agencies to discontinue sealing PCC joints, the cost to federal and state highway agencies in terms of lost pavement life, hazards to the public from blowups, and damage to bridges could be extremely large.

Objectives:

- Quantify the effect on long-term pavement performance of installing and maintaining sealed transverse and longitudinal mainline joints in PCC pavements for different pavement designs and climatic conditions. This study should not focus on the performance of individual sealant materials.
- Similarly, quantify the effect on long-term pavement performance of unsealed joints in PCC pavements for different pavement designs and climatic conditions.
- Determine the cost-effectiveness of sealing and resealing transverse and longitudinal joints in PCC pavements for different pavement designs and climatic conditions and compare to that of unsealed joints. This comparison should be based on long-term pavement performance rather than initial cost alone.

Approach: Because of the large expense in constructing and monitoring large-scale test sites, this project should be conducted in two stages:

Stage I should use information available from all SHRP LTPP SPS-4 test sites, state-sponsored test sites, and other pavement evaluation databases to determine if there is sufficient information to warrant construction and monitoring of additional test sites. Tasks for this stage should include:

- Develop uniform project evaluation criteria. This can include overall pavement performance criteria (e.g., IRI, PSR, faulting index) or specifically designed indexes based on distresses potentially related to moisture and stone intrusion (e.g., spalling blow-ups, corner breaks, transverse cracking, and pushing and cracking of bridges).

Criteria and rating schemes should be developed for visual surveys, coring analysis, and other selected evaluation methods.

- Identify all sites for evaluation. Information can be collected from the FHWA and state agencies regarding the current test sites, their design, and the performance data currently available. An experimental matrix of the selected major factors should be compiled, and attempts made to fill each combination with at least two sites.
- Field evaluation of sites. Supplemental information regarding the pavement condition at each site should be obtained through fault and profile measurements, coring, and visual inspection. The LTPP visual survey methods should be conducted for distress evaluation by certified raters.
- Analyze data and provide recommendations. Analysis of the available existing and newly collected data should result in quantification of performance differences in sealed and unsealed pavements, and evaluation of comparative life-cycle cost results for each site. The analysis should take into account the climatic, support, load transfer, and joint spacing effects at each site, and define cost-effectiveness in relation to these and other major identified factors. Recommendations for or against further study should be based on these results. If the recommendation is for further study, an experimental plan should be provided outlining the design and evaluation of Stage II test sites.

Stage II if it is deemed necessary, will be a larger effort, involving construction and at least 20 years' evaluation of carefully designed test sites in several climatic and geographic regions. Anticipated major tasks for this stage include:

- Develop the experimental design. This task requires the researcher to carefully craft a reasonable experimental design that takes into account the major pavement design, climatic, and traffic factors that affect the relationship between pavement performance and the presence of a joint seal. The effect of aggregate type on joint movement could also be included. This design should include completely sealed and unsealed joints. Also, to evaluate the effect of partially sealed joints, a hot-applied sealant could be installed and left unsealed after its initial failure in 4 to 6 years.
- Construct test sections. Careful control and detailed monitoring of the construction must be conducted to document any factors unrelated to joint sealing that may affect pavement performance. Some sections may be designed to evaluate the effect of sealing only transverse, longitudinal, or shoulder joints. Maintenance of the joint seals must be ensured by the participating agency at a level of 80 percent or better to ensure a valid comparison of sealed versus unsealed joints.
- Continue evaluation of test sections. Evaluation of the test sections should be continued using the criteria identified in Stage I. Evaluation should also include characterization of pressure generation in the pavement over time and the effect of sealed and unsealed joints on pavement migration. This evaluation could be intermittent during the first 15 years, but should be more frequent after that to ensure differentiation between the test sections.
- Analyze the data and provide recommendations. Conclusions can be drawn from the results of the experimental sites regarding pavement performance when joints are sealed, unsealed, and possibly partially sealed. Life-cycle-cost analysis should then be completed to determine when or if the expense of sealing joints in concrete pavements is worth the effort.

Current Activities: Evaluation of the SPS-4 sites is currently limited to evaluation of the condition of the joint seal materials. Failed sealants at these sites are not being replaced, and consequently the comparisons at these sites pertain to unsealed versus partially sealed instead of unsealed versus sealed joints. No research is currently funded to evaluate the effect of sealing on pavements at these sites. Several states have ongoing studies of joint sealant materials. Some of these include unsealed sections which could be included in this research.

Urgency: State agencies could apply the results of the Stage I research immediately, if it is conclusive. If the Stage I or II results find Wisconsin's premise to be true elsewhere, it could result in substantial savings in the initial cost and life-cycle cost of concrete pavements, without any decrease in overall performance.

Cost: Estimated Stage I cost is $250,000 to $300,000, and Stage II costs will depend on the scope defined in Stage I.

Duration: Completion of Stage I is expected to take 2 to 3 years from award of the project. Stage 2, if completed, will require at least 10 years for preliminary data and 15 to 25 years for final results.

A3C13-02: Bond Adhesion of Formed-in-Place Seals

Problem: The majority of states responding to a recent survey on formed-in-place joint sealant performance identified bond adhesion failure at the sealant-concrete interface as a major problem. Confronted with similar problems, several European jurisdictions have recommended use of primers for all formed-in-place sealants except for coal tar systems.

Objectives: The objectives of the proposed study are to: develop diagnostic methods necessary to characterize the surface chemistry of pavements made with different aggregates with respect to interaction with formed-in-place sealants; develop a protocol to select a primer or sealant system for various pavements under various climatic conditions; and design and evaluate field techniques for assessing the effect of geographical location and type of coarse aggregate on the performance of joint sealant-concrete interface bond adhesion.

To meet these objectives the following tasks are proposed: identify major cement-aggregate systems that are or have been used in constructing concrete roads; identify the details of adhesion failure of joint sealants occurring with various concrete types under various climatic conditions; identify, through microscopic and chemical diagnosis, the modes of adhesion failure that occur with various concrete sealant systems. Emphasis should be placed on the role of aggregates in concrete and on the chemistry of formed-in-place sealant types used in the United States; evaluate surface chemistry of cement phases and their adhesion characteristics to the sealant types. The evaluation should include surface chemical and adhesion measurements under simulated climatic conditions. The need for primers to enhance adhesion of cement phases should be recognized in the results of this task; evaluate surface chemistry of typical aggregates used in concrete as pertinent to sealant adhesion in pavement joints; evaluate adhesion of various sealants to major types of aggregates under both dry and wet conditions, and in the presence of ions

normally leaching out of concrete. Adhesion should be measured under various climatic conditions; compile and summarize surface chemical and adhesion parameters prevailing with various concretes and sealants under various climatic conditions. The need for suitable primers or modification of sealants for various types of concretes and various climatic conditions should be determined; construct pavement joints and use different primers and sealants on the laboratory scale. Test adhesion characteristics under various climatic conditions; define and develop protocols to select primer or sealant systems for various concretes and climatic conditions; develop diagnostic testing procedures necessary for successful implementation of technology; and prepare a final research report documenting all activities and results of research.

Cost/Duration: It is estimated that this study will cost $500,000 over 3 years.

Current Activities: A search of the TRIS database failed to identify any research in this area.

Urgency: The dollar payoff of this technology across the United States is in the hundreds of millions of dollars. The urgency of this research is high.

A3C13-03: Evaluation of Pavement Joint Seat Failures

Problem: There is very little information on the condition of new joint seal installations, and the type and rate of joint seal failures.

Objectives: Evaluate the pavement joint seal condition starting immediately after installation. Determine the type and source of initial failures and their rate of progression through nondestructive testing over a 3-year period.

Current Activities: No national research activities are known to be under way in this area.

Urgency: A database with information on failure mode and rate for pavement joint seals is needed to help understand the joint seal failure problems which exist today.

A3C13-04: Infrared Analysis to Detect Faulty Joint Sealant Materials

Problem: Improper installation of joint sealant material is one of the major causes of poor joint sealant performance. Some of the typical deficiencies noted are joints not properly cleaned before being filled with joint sealant, overheating of the hot-applied sealants, and improper mixing of the two-component joint sealants. The results can be a brittle material, or one that does not cure. These joint sealant problems can be overcome by employing current analytical technology to ensure proper mixing ratios and installation procedures.

Objectives: Develop a user-friendly database of Fourier-Transform Infrared Spectroscopy (FTIR) readings from different joint sealants. These readings can be used by engineers to

perform sealant quality control checks. FTIR readings identify the chemical characteristics of the joint sealants. Joint sealants that are improperly mixed, overheated, or contaminated can be detected.

Current Activities: The Pavement Systems Division of the U.S. Army Engineer Waterways Experiment Station (WES) is currently taking FTIR spectra on joint sealants submitted for federal specification conformance testing (SS-S-1401C, SS-S-1614A, and SS-S-200E) for use on military projects. WES has also performed several site investigations of failed rigid pavement joint sealants using this technique.

Urgency: The detection of faulty joint sealants during installation will have a significant impact on preserving and extending the life of the nation's roadway system.

A3C13-05: Evaluation of New Pavement Joint Sealants and Installation Procedures

Problem: Some very expensive joint sealants have been developed over the past 10 years. However, the rate of joint seal failures has not markedly improved. Although sealants may pass laboratory tests, eventual failures are often blamed on installation procedures.

Objectives: Establish a joint sealant product and installation evaluation program for comparison of product performance.

Current Activities: Some evaluations of joint sealants are being done on a project or statewide basis. None are known to include a combined evaluation of sealant and installation.

Urgency: Performance of new products could be determined more reliably through a combined product and installation evaluation.

A3C13-06: Analytical Investigation of Adhesive Stresses in Highway Joint Seals

Problem: Highway joint seals fail at a rate which is quite unacceptable. Recent studies have shown that adhesion failure is the most troubling obstacle to obtaining long-term effective seals. Interest in this problem has grown in the past 5 years and this has led to research which has followed three main routes: field studies, laboratory studies, and materials research. The research proposed here follows a fourth route, stress analysis of the seal system. Stress analysis has helped in the design of many other types of physical systems and its application to the problem of adhesion failure of highway joint seals is long overdue.

Stress analyses to determine the magnitudes and distributions of adhesive stresses associated with specific material properties, seal configurations, and joint distortions would complement the other forms of research currently in progress. Many combinations of material properties and seal geometrics can be investigated rapidly and economically to determine which combinations are most likely to succeed in the field. This can save much of the expense of laboratory and field studies. Analytical parametric studies can also help in the development of new or modified materials.

Part of the reason that stress analyses for joint seal systems have not yet been accomplished is that elastomeric seals behave in a complex manner which is not adequately represented by traditional methods of stress analysis. Furthermore, there has been very little work on defining the mechanical properties of sealant materials. Typical elastomeric sealant materials (such as polymer modified asphalt and silicones) stress relax at a very fast rate. Analyses which fail to account for this behavior are subject to error. Seals also incur large strains, so geometric non-linearity must be considered in the analysis. The material properties of most sealant materials also vary with temperature. While these features of the seal system make analysis difficult, preliminary studies indicate that developing an appropriate analysis method is entirely feasible and practical.

Objectives: The objectives of the proposed research are to develop a material constitutive equation which counts for the critical features of sealant behavior; develop an analysis algorithm which permits modeling the pertinent material and geometric characteristics; test material to quantify parameters used in the constitutive equations; perform analyses to determine adhesive stress magnitudes and distributions; and correlate analysis results with laboratory testing. The research should be arranged in two phases. Phase I would consist of preliminary material testing, development of the algorithm, and analyses to verify the approach. Phase II would consist of testing additional materials to determine their visco-mechanical properties and perform parametric studies using the analysis method developed in Phase 1.

Cost/Duration: The estimated cost for this effort is $450,000 over 3 to 4 years.

A3C13-07: Backer Rod Effects on Performance of Sealants

Problem: Several types of backer rods are presently available for use in pavement joint systems. However, no data are available regarding the effects of the various materials on both the long- and short-term performance of the joint sealant system.

Objectives: Perform an evaluation of sealant systems employing the different types of backer rod materials. The study should include the following material properties: absorptive and non-absorptive; gassing (open cell) and non-gassing; and resilient and rigid. The study's goal should be to define the best backer rod materials for differing sealant materials.

Current Activities: No major research activities are presently being performed in this area.

Urgency: Any study which defines the parameters which affect the performance of the sealing system is of great benefit. Generally, most early distress and a high percent of later life distress in concrete pavement are problems stemming from joint design and construction.

A3C13-08: Development of a Design Procedure for Control Joint Depth and Width

Problem: Most designers currently do not perform a formal design when sizing the joints for pavement or any flatwork (portland cement concrete) system. The current state of standard practice includes utilization of state DOT standards for all types of slabs, or simply specifying a control joint with no consideration of width or depth. These methods are employed without consideration of slab lengths, widths, or the temperature conditions at the time of placement. Generally, the joint system is not designed, and joints are installed the width of standard saw blades.

Objectives: Develop a rational design procedure for sizing the control joints in portland cement concrete flatwork. The design procedure should consider both compression and non-compression seals. The method should include a consideration of ambient temperatures at the time of placement, slab thicknesses, temperature gradients, and other environmental factors affecting the movement of the slabs.

Current Activities: No major research activities are presently being performed in this area. The SHRP program developed cracking sealing equipment and materials, but did not consider control joint design in new construction.

Urgency: A practical procedure to design control joint systems is clearly needed. The implementation of such a procedure would reduce the number of premature slab failures caused by poor joint details.

A3C13-09: Standardizing the Cleanliness and Dryness of PCC Joint Wall Conditions Prior to Seal Installation

Problem: For many years the question has been asked, “How clean is clean enough?” in regard to PCC joint preparation prior to sealing. A precursor to that question is, “How do I know how clean and dry the joint is?” Because of the lack of methods for quantifying the cleanliness and dryness of PCC joints prior to sealing, agencies must rely on control of installation processes to ensure proper joint seal installation. Because inspectors are not able to observe every step in the sealing process, it is very easy to miss the occurrence of damp joints and joint walls that are improperly cleaned. If an inspector does identify a low level of cleanliness, there is no objective standard against which to measure the contractor’s work.

Formed-in-place joint sealants rely on a bond between the seal material and the joint wall to provide watertight performance. Unremoved sawing slurry, moisture, oil, and old sealant can effectively inhibit this bond, resulting in seal failures within a year or less. Although formed-in place sealant manufacturers are working to develop materials that are less sensitive to joint wall cleanliness, this is not expected for many years.

The cost of this inability to control the joint seal installation process has been great in terms of material costs for additional sealing, damage to pavements with moisture-susceptible base materials, and additional safety hazards to highway workers.

Objectives: This research will encompass three main objectives:

1. Develop fast, easy to use equipment and methods for quantifying the cleanliness and dryness of PCC joint walls prior to sealant installation.
2. Correlate the quantified joint cleanliness and dryness levels with sealant bonding properties in the lab using the sealant materials commonly in use.
3. Develop detailed video demonstrations, manuals, product alerts, and specifications for application and use of this equipment.

Key Words: Joint seal, adhesion, specifications.

Current Activities: No activity is known to be currently under way in this area.

Urgency: Agencies are becoming frustrated with the short effectiveness life of formed-in-place PCC joint seals, which is in many cases the result of low-quality cleaning operations. Particularly in wetter climates with poorly draining base materials, the need to maintain effective joint seals is critical. Developing this type of equipment and methodology is expected to improve the sealing industry in the same way as profilography has improved the smoothness of highway pavements in the last 40 years.

Cost/Duration: Depending on the cost of equipment design and development, the expected cost will be between $150,000 and $250,000 and development is expected to require 24 to 36 months.

A3C13-10: Anchoring System for Mechanical Bridge Deck Joints

Problem: Bridge deck joints come in a wide variety of sizes, shapes and configurations. One thing that is consistent with all types of joints is the problem of permanently affixing them to the concrete. Designers have a myriad of anchorage systems to choose from such as expansion, epoxy resin, cast-in, and post-tensioned anchors, to name a few. However, very few data exist on how these systems perform under constant impact loading.

Objectives: Develop test data on the performance of various anchorage systems on in-service bridge decks.

Current Activities: No research at present.

Urgency. Bridge deck joint failure results in substructural deterioration. In addition, loose joint components result in serious hazard to vehicular traffic. Anchorage breakdown is one of the major causes of bridge deck joint failure.

COMMITTEE A3C14 – POLYMER CONCRETES, ADHESIVES, AND SEALERS

A3C14-01: Development of Guidelines for Design, Construction, and Evaluation of Polymer Concrete Overlays

Problem: Polymer concrete (PC) bridge overlays, which consist of a polymer binder, e.g., epoxy or polyester, and fine aggregates are constructed with a thickness range of 0.25 to 1.0 in. They have the advantages of (1) adding very little dead load; (2) very fast cure times; (3) shallow depths, which eliminate need for raising approach slabs; (4) transition from overlaid lane to non-overlaid lane during construction; (5) essentially waterproof, long-lasting wearing surface; and (6) excellent skid resistance. There is no current design procedure to determine interfacial and inplane overlay stresses due to thermal changes and shrinkage, which are functions of polymer type, thickness, and environmental conditions. Construction guidelines are needed to ensure proper surface preparation application procedures and equipment, vibration and curing procedures. Non-destructive test methods to evaluate properties of overlays are needed. Construction guidelines and evaluation methods for quality control and predicting long-term performance are not available.

Objectives: The objectives of the research are to

1. Review previous research, specifications, and procedures for PC overlays.
2. Determine the primary factors which influence the stresses in PC overlays.
3. Develop a design procedure.
4. Develop construction guidelines related to surface preparation, mixing and placement, consolidation, finishing, and curing.

5. Determine procedure for evaluating bond to substrate and properties of PC using NDT where feasible.
6. Prepare specifications.

Key Words: Polymer concrete, overlays, construction, design, bridge decks, evaluation.

Related Work: Many PC overlays have been installed based on trial and error. Rules of thumb have been developed which generally result in adequate performance. Limited analytical and experimental research indicates that it is possible to predict stresses in PC overlays due to (1) thermal effects caused by differences in coefficients of thermal expansion of concrete and PC and (2) shrinkage. The AASHTO-AGC-ARBTA “Guide Specifications for Polymer Concrete Bridge Deck Overlays” (October, 1995) was developed as a first step. Considerable performance history of PC overlays over a 20-year period is available.

Urgency/Priority: PC overlays are one of the most promising and effective rehabilitation procedures for bridge decks. The overlay can be placed overnight with little increase in dead load. The overlays provide excellent durability and require little or no change in approach slabs or drainage. With 40 percent of the nation’s bridges in need of repair, PC overlays offer a proven, cost-effective procedure for repair.

Cost: The estimated cost is $300,000.

User Community: Bridge construction and maintenance engineers and bridge contractors.

Implementation: The findings of the research can be implemented in several ways:

- User friendly software,
- Regional seminars, and
- Sessions and/or seminars at TRB.

Effectiveness: The research will result in (1) the extended life of bridges; (2) construction performed at night resulting in minimal bridge closures and traffic delays; and (3) rehabilitation method applicable to older bridges which can only accept a minimal increase in dead load.

A3C14-02: Concrete Bridge Deck Crack Repair

Problem: A recommended practice is required for the repair of cracks in concrete bridge decks to seal them effectively or structurally repair them to prevent further damage by chloride intrusion.

Objectives: Identify materials and procedures that should be used for the repair of various types of cracks normally found in concrete bridge decks. Develop a guide to assist engineers in writing specifications for better and longer lasting repairs.

Cost: The estimated cost of this study is $100,000.

Current Activities: None.

Urgency: Effective sealing of cracks in bridge decks will reduce chloride intrusion to the reinforcing steel, thus reducing the possibility of corrosion and increasing bridge deck service life.

A3C14-03: Development of Guidelines for Selection, Application, and Evaluation of Sealers for Concrete

Problem: NCHRP Synthesis 209 identified 273 sealers for concrete. The number has likely increased since the synthesis was prepared. DOTs often consider the application of a sealer to protect and extend the life of concrete. Unfortunately, DOTs have no guidelines for selecting a sealer from the many available, no guidelines for applications that are customized for the unique requirements for concretes used in transportation, and no guidelines for the evaluation of sealers so that a cost-effective selection can be made. Although the application of a sealer can be the cost-effective solution to maintaining and extending the life of concrete, sealers are rarely used because of the lack of consensus on guidelines.

Objective: The objective of this research is to develop guidelines for the selection, application, and evaluation of sealers used to maintain and extend the service life of concrete.

The research would include the following tasks:

- A literature survey to identify relevant information,
- The development of guidelines for the selection of the optimum sealer for a given set of requirements,
- The development of guidelines for the proper application of selected sealers in typical transportation applications,
- The development of guidelines for the evaluation of sealers, and
- The preparation of a summary report with guidelines attached.

Key Words: Sealers, concrete maintenance, concrete protection, hydrophobic, pore blockers, barrier coatings.

Related Work: The most complete work on sealers is NCHRP Synthesis 209, published in 1994.

Urgency/Priority: Sealers can provide an economical alternative for maintaining and protecting concrete. Incorrect applications can cause reduced skid resistance and negligible benefits. Consensus guidelines are needed so that sealers can be correctly used in appropriate applications. Research has a high priority.

Cost: The estimated cost is $300,000.

User Community: AASHTO, FHWA, and ACI should have interest in the research.

Effectiveness: Use of the guidelines results in correct and increasing use of sealers and cost-effective maintenance and increased life of concrete.

A3C14-04: Development of Polymer Concretes for Use in Bridge Deck Overlays

Problem: Evaluations in recent years have shown that some polymer concrete overlays are economical alternatives for extending the service life of bridge decks exposed to deicing chemicals, particularly when the protective overlay must be installed with a short lane closure time. However, polymer concretes used in bridge overlays need to have the appropriate flexibility, tensile strength, adhesion strength, and durability in the presence of moisture to provide a long service life. The ASTM D 638 procedure is currently used to measure the elongation and tensile strength of neat specimens. Overlays have performed reasonably well when the binders tested in the laboratory at 73^0F and at an age of 7 days exhibit a tensile strength of 1,500 to 4,000 psi and an elongation at break of 20 to 90 percent. It is accepted that the flexibility of binders is temperature dependent but studies need to be done to show how currently used binders perform at temperatures other than 73^0F, including the extreme temperatures of zero^{0}F and 140^0F typically encountered in service. Also, overlays exhibit a minimum tensile adhesion strength of 250 psi when tested in accordance with ACI 503R. The overlays are typically applied to dry surfaces at

temperatures of 65^0F to 100^0F and tested under similar conditions. Studies need to be done to measure the adhesion strength at other temperatures including 0^0F and 140^0F and when moisture is present in the substrate. Finally, studies should be done to show the effects of the aging of the polymer concrete and long-term exposure to moisture in the substrate.

Objective: The objective of this research is to identify and develop the most suitable polymer concretes for use as overlays in bridge decks. Performance will be based on measurements of the tensile strength and elongation at break (ASTM D638) of selected epoxy, polyester, methacrylate, and urethane binders and the tensile adhesion strength (ACI 503R) of selected polymer concretes made with these binders, when tested in the ranges of temperatures, moisture conditions, and overlay ages typically encountered on bridge decks.

This will be done through the following tasks:

- Literature Search and Industry Contacts. The literature should be reviewed and appropriate contacts should be made with industry to identify polymer concretes that are used for overlays on bridge decks. Prepare a summary table that lists the generic types of polymer binders and concretes, provides the physical and chemical properties of the binders and concretes, and indicates the performance record as an overlay. At a minimum the table should include the following binders: epoxy urethane blends; epoxies flexibilized with urethane, nitril rubber, polyglycol or flexible hardeners; polyester styrenes, methacrylates; and urethanes. In addition, the table should include binders with the following ranges of properties.

Viscosity	<200 cp	200 - 2,000 cp	>2,000 cp
Gel time	10 - 20 min	20 - 40 min	
Tensile elongation	<20%	20 - 70%	>70%
Tensile strength	<1,500 psi	1,500 - 4,000 psi	>4,000 psi

  The table shall be used to identify the chemical and physical properties of the polymer concretes with the best performance record and to provide for the development of a new optimum binder.
- Measure physical properties. Samples of at least 24 generic binders that cover the range of types and properties identified in Task 1 shall be obtained for testing. The samples shall include one or more newly formulated binders that should provide optimum performance on bridge decks as well as binders and concretes that have good performance histories. The choice of binders shall be approved by the NCHRP panel. At a minimum the following measurements must be made on the binders or the concretes — viscosity, gel time, tensile strength and elongation (ASTM D638), bond strength (ACI 503R), permeability (AASHTO T277), and compressive strength development as a function of age. Measurements shall be made at 0^0F, 35^0F, 72^0F and 120^0F.
- Determine effects of moisture in substrate. A minimum of 6 binders, including the newly developed binders (to be approved by the panel) shall be used in overlays that are placed on concrete slabs with three moisture contents (ranging from dry to saturated). The bond strength shall be measured. A fourth set of overlays shall be placed in which the substrate is dry but then exposed to 100 percent relative humidity

for 2 years. The bond strength shall be measured at 1 day, 1 month, 6 months, 1 year and 2 years.

- Determine the effects of age. A minimum of 12 binders including newly formulated binders (to be approved by the panel) shall be studied to determine the effects of age on tensile strength and elongation, bond strength, and permeability to chloride ion. One set of specimens shall be aged in an ultraviolet light chamber and tested as necessary to show deterioration in properties. A second set of specimens shall be aged in an outdoor exposure area and tested at 7 days, 1 year, and 2 years. A third set of specimens shall be prepared and turned over to NCHRP so that arrangements can be made for long-term outdoor exposure and subsequent testing.

Cost and Duration: The estimated funding for this project is $300,000 for the tasks noted above. The research will require approximately 3 years to complete.

Urgency and Payoff Potential: Results are urgently needed because millions of dollars are spent annually on polymer bridge overlays. Optimum properties must be identified to obtain the long service life needed to ensure that use of polymer overlays will continue to increase. The research will help identify and refine the specifications for the most durable and cost-effective polymer overlay systems.

A3C14-05: Properties of Polymer Concretes Used in Bridge Deck Overlays

Problem: Polymer concretes used in bridge overlays need to have the appropriate flexibility, tensile strength, adhesion strength and durability in the presence of moisture to provide a long service life. The ASTM D 638 procedure is currently used to measure the elongation and tensile strength of heat specimens. Overlays have performed reasonably well when the binders tested in the laboratory at 23°C (73°F) and at an age of 7 days exhibit a tensile strength of 10 to 27 MPa (1,500 to 4,000 psi) and an elongation at break of 20 to 90 percent. It is accepted that the flexibility of binders is temperature dependent but studies need to be done to show how currently used binders perform at temperatures other than 23°C (73°F), including the extreme temperatures of minus 18° and 60°C (0° and 140°F) typically encountered in service. Also, overlays exhibit a minimum tensile adhesion strength of 1.72 MPa (250 psi) when tested in accordance with ACI 503R. The overlays are typically applied to dry surfaces at temperatures of 18° to 38°C (65° to 100°F) and tested under similar conditions. Studies need to be done to measure the adhesion strength at other temperatures including minus 18° and 60°C (0° and 140°F) and when moisture is present in the substrate. Finally, studies should be done to show the effect of the age of the polymer concrete on these properties.

Objectives: Measure the tensile strength and elongation at break (ASTM D638) of selected epoxy, polyester, methacrylate, and urethane binders and the tensile adhesion strength (ACI 503R) of selected polymer concretes, when tested in the ranges of temperatures, moisture conditions, and overlay ages typically encountered on bridge decks. The research will help identify and refine the specifications for the most durable polymer overlay systems. The published results of this research will allow engineers to specify materials and procedures which will produce longer lasting overlays.

Costs: The estimated cost of this effort is $400,000, including $150,000 to study age effects.

Current Activities: None at temperatures other than 23°C (73°F).

Urgency: Results are urgently needed because millions of dollars are spent annually on polymer bridge overlays. Optimum properties of polymer overlays must be identified to obtain a long service life.

A3C14-06: Non-Destructive Field Test to Measure Polymer Concrete Overlay Strength

Problem: Simple, non-destructive, rapid field tests are needed to measure the strength of polymer concrete overlays, so engineers can determine when to allow bridges to be opened to traffic without affecting the service life of the overlay.

Objectives: The objectives of this study are to

- Identify the relationships between strength development and curing temperatures for generic polymeric materials used to construct polymer concrete overlays.
- Develop a simple, non-destructive test that can be used in the field to measure overlay strengths. This research will allow engineers to know when overlays have attained the proper strength and are ready to be opened to traffic. A user's guide with nomographs showing the relationship between strength and age at various temperatures for generic groups of polymer materials and a test method for measuring strength would be helpful extending the service life of polymer concrete overlays to their full potential.

Cost: The estimated cost of this effort is $200,000.

Current Activities: None.

Urgency: The use of polymers is increasing and therefore this study is needed to reduce failures and increase service life of overlays.

COMMITTEE A3C15 – CORROSION

A3C15-01: Service Life of Rehabilitation Treatments for Concrete Structures

Problem: Selecting the optimum method of rehabilitating concrete structures includes the calculation of the cost-effectiveness of all the methods, which would provide a solution which is feasible from the engineering standpoint. While several research studies have generated data on the costs of rehabilitation, reliable information on service lives remains illusive. Much of the data on service lives has been developed through expert opinion, rather than from measurements of field performance, and this in turn limits the utility of decision models.

Determining the service lives of rehabilitation is a difficult task, because of the number of factors which affect field performance, and is especially difficult for those methods which have been in use for only a short time. However, the information is vital to highway agencies in determining the optimum treatment for structures, thereby giving a high priority to the research. Newer methods of investigation such as measurements of the rate of corrosion provide the opportunity to adopt new approaches to determining the service lives of treatments applied to corrosion-damaged bridges. There is much less information available on methods of rehabilitating prestressed concrete components than reinforced concrete components, and the latter present additional engineering complexities. In view of the numbers and importance of prestressed concrete bridges, it is important that the service lives of rehabilitation treatments applied to prestressed components be developed using the same methodology as for reinforced concrete components.

Objectives: The objectives of the research are to

1. Develop a methodology for determining the service life of rehabilitation treatments applied to corrosion-damaged, reinforced, and prestressed concrete bridge components.
2. Apply the methodology to determine the service lives of rehabilitation methods in common use. As a minimum, the methods shall include cathodic protection, electrochemical chloride removal, concrete overlays, waterproofing membranes, shotcrete repairs, and pier jacketing.

Cost: $500,000.

Duration: 36 months.

A3C15-02: Criteria for Removing Concrete and Cleaning Reinforcing Steel in Bridge Rehabilitation

Problem: The criteria used for the removal of concrete when rehabilitating decks and substructure components have a substantial influence on the cost of the repair and the extension of service life of the component. The removal of sound, salt-contaminated concrete, without damage to concrete left in place, is both difficult and expensive. A number of criteria are in use, ranging from removing only concrete which is delaminated, through criteria based on the measurement of corrosion potentials, to exposure of all the steel in the top mat of reinforcement.

The cleaning of corroded reinforcement is also a tedious, difficult, and expensive operation, especially when cleaning the underside of bars. It is known that the corrosion products on the steel contain chloride ions, and that, if these are not removed, corrosion will be initiated as these sites and the service life of the rehabilitation will be reduced. As in the case of concrete removal, several criteria for cleaning bars exist, though many make reference to SSPC specifications for the surface preparation of steel.

Research is needed to investigate the relationship between the extent of concrete removal and bar cleaning on the service life of concrete patch and overlay repairs with the goal of establishing models of cost-effectiveness applicable at the project level.

Objectives: The objectives of the research are to

1. Develop a methodology for determining the relationship between the criteria for concrete removal and bar cleaning, and the service life of concrete in patch and overlay repairs.
2. Apply the method to various criteria in common use and to others which may be more appropriate.
3. Develop a model that includes costs and the relationships between concrete removal and bar cleaning criteria on the service life of concrete repairs such that the most cost-effective criteria for any particular situation can be computed.

Key Words: Bridge deck repair.

Related Work: An NCHRP synthesis addressing the state-of-practice in the application of criteria to removing concrete and cleaning reinforcing steel in bridge deck repairs is anticipated. Any results available from this anticipated synthesis are to be used as input to this proposed project.

Urgency/Priority: The massive amount of bridge maintenance being done annually in deck repairs and rehabilitation makes it imperative that the most cost-effective methods be applied to this work. Since most of this activity is conducted through contract maintenance, clear quantitative criteria are needed to specify and control these contracts.

Cost: It is anticipated that 3 years will be required to conduct this proposed research at an estimated cost of approximately $350,000.

User Community: AASHTO, FHWA.

Implementation: A guide to specifying criteria for rehabilitating reinforced concrete bridge decks is anticipated.

Effectiveness: Successful completion of this project should enable highway agencies to extend the life of concrete bridge deck repairs by at least one year beyond the current service life of repairs.

A3C15-03: Long-Term Performance of Corrosion Inhibitors in Concrete Structures

Problem: Corrosion inhibitors for use in concrete have been known for many years and usage in new concrete construction has increased steadily during the past 15 years. Several research studies have identified and tested corrosion inhibitors for use in the rehabilitation of concrete structures. The effectiveness of corrosion inhibitors, especially in rehabilitation construction, remains controversial. This is largely because corrosion inhibitors can be of three types: anodic, cathodic, or mixed mode. When concrete is removed in a repair it is usual to expose some, but not all, of the reinforcement. The new concrete will normally cause the exposed reinforcement to be cathodic with respect to reinforcement in the original concrete but such is not necessarily the case, especially if all the corrosion products are not removed from the exposed reinforcement. As a result of

the number of variables, and the complexities of the corrosion process, corrosion inhibitors perform very differently depending upon the individual circumstances. Other factors affecting the long-term performance of corrosion inhibitors, such as cracks in the concrete and consumption of the inhibitor, occur in both new and rehabilitation construction. Consequently, for this particular study, it would be illogical to limit the study to only rehabilitated structures.

Objectives: The objectives of the research are to

1. Investigate the mechanisms through which inhibitors control the rate of corrosion of steel in concrete.
2. Quantify the factors that determine the effectiveness of corrosion inhibitors in reinforced and prestressed concrete.
3. Determine the long-term effectiveness of corrosion inhibitors in new and rehabilitation construction in reinforced steel and prestressed concrete components.

Cost: $450,000.

Duration: 60 months.

A3C15-04: Performance Specification for Bridge Deck Waterproofing Membrane Systems

Problem: Waterproofing membranes can be an effective method of protecting both the concrete and embedded reinforcement in new and existing bridge decks. Except for a few states, membranes are used only sporadically in the United States, often to provide only a short extension of service life on existing decks. NCHRP Synthesis Report 220, Waterproofing Membranes for Concrete Bridge Decks, noted that North American practice has changed little in the past 20 years. The vast majority of membranes installed in the U.S. are preformed products, and the market is dominated by three products introduced in the 1970s. A 1995 FHWA scanning tour of bridge technology in Europe observed the broad range of materials and widespread use of waterproofing systems in protecting bridge decks in aggressive environments.

The waterproofing membrane is only one component of waterproofing systems that may include primers, adhesives, protection board, tack coat, and bituminous concrete layers. The performance of the system is determined by the complex interaction of material factors, design details, and quality of construction. Research is required to define performance requirements for waterproofing systems, to be followed by development of a suite of quantitative prequalification tests and quality assurance procedures, the findings to be embodied in a performance specification. The specification should cover the material requirements for the membrane, adhesives, and protection board (if used), together with requirements for installation. The performance specification should also include provision for life-cycle costing so that systems that offer superior performance can compete on an equitable basis with systems that have low initial cost, but a short service life.

Objectives: Develop a performance specification for bridge deck waterproofing membrane systems based on a quantitative definition of performance requirements, objective prequalification tests, and a life-cycle cost analysis. The objective is to encourage competition between a wide range of products and processes, all of which will perform satisfactorily in the field.

Cost: $350,000.

Duration: 36 months.

A3C15-05: Condition Survey Methods for Concrete Structures: Field Validation and Calibration-Selected Methods, and Subsequent Protocol

Problem: As a follow-up to the SHRP effort in concrete bridge component assessment, there is a need for more detailed study of the significance of the condition data that can be obtained from the various commercially available instruments sensing corrosion parameters, defining exactly what is the relationship of the instrument data to observed concrete damage, and evaluation of the utility of rate-of-corrosion measurements in determining when to rehabilitate and how to rehabilitate a bridge (or a bridge component). Further study is needed on how to measure concrete permeability, on how to measure the integrity of membranes, and how to measure the effectiveness of sealers. Also, the internal relative humidity of the concrete is needed to complement data that can be obtained on corrosion potential and on chloride content to assist in current anomalies in the data being developed. Finally, there is a need for a condition survey protocol to assist agencies in estimating the cost of condition surveys and the difficulty of executing these surveys.

Objectives: This proposed project has the following objectives:

1. For a selected set of commercially available rate-of-corrosion devices, establish the significance of the measure values from the instruments, and the relationship of the measured values to observed corrosion damage.
2. Conduct field trials comparing each of the instruments and the techniques of applying them to investigate (a) integrity of membranes, (b) effectiveness of sealers, and (c) permeability of concrete; and correlate the instrument measurements with field performance of the concrete.
3. Develop a procedure suitable for the measurement of the internal relative humidity of concrete under field conditions.
4. Prepare a recommended standard test procedure for the measurement of each of the concrete properties investigated.
5. Develop a condition survey protocol which includes the costs of each method of investigation (including equipment, training, and personnel time), the quality of data, and the utility of data, to guide agencies in planning condition surveys.

Key Words: Concrete corrosion, field measurement, corrosion instrumentation, bridge condition survey.

Related Work: SHRP project "Assessment of Physical Condition of Concrete Bridge Components" and SHRP Report SHRP-S-330 provide much of the initial work on this area. This project is proposed to complete the work started in that effort and make it more fully usable by field agencies.

Urgency/Priority: This proposed project is vital to moving bridge condition surveys forward in applying non-destructive testing to maximize the resources available to preserve our reinforced concrete bridge infrastructure.

Duration/Cost: It is anticipated that this proposed research will require an estimated 36 months and $500,000 to complete.

User Community: AASHTO, FHWA.

Implementation: A published guide to bridge condition assessment supplementing the existing guides and manuals is anticipated.

Effectiveness: Successful completion of this project should yield a significant increase in the extension of reinforced concrete bridge life with the same rehabilitation resources currently being expended.

A3C15-06: Durability in Structural Highway Concrete

Problem: Concrete research has investigated the mechanical properties of concretes that exhibit high strength or high rate-of-gain of strength. Methods are available for measuring these properties. Both of these characteristics can be advantageous in highway environments but durability is of equal or greater importance. Research is needed to define the requirements for high quality structural concrete which can be produced by the ready-mixed concrete industry and which will provide superior durability performance in the highway service environment. This research needs to include development of an "end-result" specification for highway concrete that incorporates durability requirements.

Objectives: The proposed project objectives include the following:

1. Refine and quantify the requirements for superior concrete having at least the following characteristics:
    a. Capable of being produced and placed with existing equipment.
    b. Controlled strength (a low standard deviation is viewed as being more important than high strength).
    c. Very low or negative shrinkage.
    d. Low permeability.
    e. High resistivity.
    f. Resistant to deterioration by sulfate attack, freezing and thawing, and alkali-aggregate reactions. In addition, it would be very desirable that the concrete not require air entrainment for resistance to freezing and thawing or mechanical energy for consolidation.

2. Investigate concrete mixtures and identify materials and mixture proportions that will produce concrete with the above listed performance requirements.
3. Review existing concrete specifications, especially those with end-result requirements and payment incentives/disincentives; and prepare specifications in an end-result format to guide the production of concrete meeting the requirements defined above.

Key Words: Concrete durability, specifications.

Related Work: Previous SHRP concrete research program.

Urgency/Priority: This proposed research is considered to be the next step required to extend the functional and maintenance-free service life of highway and bridge concrete structures.

Cost: It is anticipated that this proposed project will require 4 years and approximately $500,000.

User Community: AASHTO, FHWA, NACE, APWA.

Implementation: Publication of the specification for adoption by highway construction and maintenance agencies.

Effectiveness: Successful completion of this proposed research project can substantially increase the value received for construction and maintenance dollars expended in concrete placed.

A3C15-07: A Decision Model for Rehabilitating Concrete Bridges

Problem: SHRP Contract C-104 was envisaged as the "umbrella" project for the structures research program. It was intended to produce a decision model, applicable at the project level to reinforced and prestressed concrete bridges, which would identify the most cost-effective treatment. The original concept of the structures program was that the products of Contract C-101 would permit a reliable determination of the condition of the bridge, and Contracts C-102 and C-103 would develop a number of options for protecting and rehabilitating bridge components. Contract C-104 would then develop a model which would determine the most cost-effective treatment, and time of intervention, based on the existing and future condition of the bridge, and consideration of all the options known to be technically viable.

The products of Contract C-104 were a decision model applicable to corrosion-damaged reinforced concrete decks and substructures, and a computerized version of the model applicable only to bridge decks. While a number of options exist for further development of the model, including its extension to components which are prestressed and to those which exhibit deterioration from causes other that corrosion, the fundamental structure of the model needs to be examined before modules are added to the current model. The decision model produced under Contract C-104 relies on the chloride ion content of concrete and on empirical relationships to physical distress in concrete. This approach has two major drawbacks; it does not make use of the large suite of assessment

techniques developed in Contract C-101, and a theoretical approach, while limited by existing data, is more fundamentally sound and amenable to refinement. Difficulties also were encountered in developing models to predict the future condition of rehabilitated components.

Objectives: The objectives of the research are to

1. Undertake a critical examination of the decision model developed under Contract C-104, especially with respect to the range of applicability and methodology employed.
2. Develop a new decision model, in both paper and computer versions, which is more consistent with the concept of the SHRP research plans, and is applicable to the deck and substructure components of reinforced and prestressed concrete bridges.

Cost: $350,000.

Duration: 24 months.

A3C15-08: End-Result Specifications for Highway Concrete

Problem: One of the goals of the Strategic Highway Research Program was to improve the basis for the prediction and control of concrete properties, and to improve the performance of cements and concretes. The concept was to conduct research to improve the understanding of how the properties of concrete depend on the characteristics of cements, admixtures, and aggregates and how the microstructure of concrete is affected by the properties of the fresh concrete, the hydration reactions and deterioration processes. A specific task within the research plan was to develop a superior concrete for highways by exploiting the results of the fundamental studies to identify concretes which have virtually no large flaws and very low permeability. It was further noted that the concretes would develop design properties rapidly and have greatly extended service life.

The project on concrete microstructure developed a number of models for aggregate gradation, packing, thermal effects in concrete pavements, curing, interfacial microstructure, permeability and porosity, as well as a method for measuring permeability, but it did not lead to the development of the superior concrete envisaged in the original research plans or the specifications for superior concrete listed in the contracting plan.

The highway industry has not only improved the quality of concrete in pavements and structures in recent years but has also introduced end-result specifications. Such specifications usually use compressive strength as the basis of acceptance (and as the index of concrete quality) though dimensional requirements such as pavement thickness or reinforcement cover may be included where applicable.

Typically, end-result specifications do not include requirements for durability, which is crucial to satisfactory performance in the highway environment. Further, there has been little documentation of the quality of concrete which has been placed (as opposed to specified), and its performance in pavements and structures in recent years. This is especially true of the “covercrete,” the concrete protecting the reinforcement (or the surface and near-surface concrete in unreinforced concrete) which is of a lower

quality than the “heartcrete” (the concrete in the middle of a member), and dictates the service life of the concrete.

Objectives: The objectives of the research are to

1. Review existing concrete specifications, particularly those with end-result requirements and payment incentives and disincentives.
2. Conduct a field survey to characterize the quality of concrete, and its performance, in pavements and highway structures.
3. Prepare end result specifications, including payment clauses, applicable to concretes which will be durable in pavements and highway structures.

Cost: $200,000.

Duration: 18 months.

A3C15-09: A Model Specification for Watertight Deck Joints

Problem: From the corrosion standpoint, the rationale for research on deck joints is that a significant proportion of corrosion damage to beam and substructure components is the result of leaking expansion joints. Some agencies have drafted specification requirements and acceptance requirements for deck joints, but these tend to address only limited characteristics and additional problems such as fatigue failures in modular expansion joints have recently been identified. Since the physical testing of expansion joints is very expensive, the development of specifications lends itself to the phased approach, which was used successfully in the NCHRP for the development of specifications for bridge bearings. The first phase requires the preparation of model specifications based on study of the literature, personal contacts, and field observations, but not including physical testing. A second phase, to include physical testing to refine the specification requirements, could be undertaken, if necessary.

Objectives: The objectives of the research are to

1. Investigate the factors which have the greatest influence on the long-term performance of watertight, bridge expansion joints.
2. Prepare a model specification for watertight, bridge expansion joints. The specification is to include requirements for loading anchorage, materials, construction, replacement, and acceptance testing.
3. Develop a work plan for completing gaps in the model specification.

Cost: $150,000.

Duration: 12 months.